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Final Report

Volume I of VIII
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PREPARED BY

Harding Lawson Associates
Environmental Science and Engineering, Inc.

PREPARED FOR

PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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U.S. FISH AND WILDLIFE SERVICE

COLORADO DEPARTMENT OF HEALTH

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PREFACE TO THE FINAL ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY

The Rocky Mountain Arsenal Offpost Operable Unit (OU) Endangerment Assessment/Feasibility Study (EA/FS) is presented in eight volumes. The contents of each volume are outlined below. To assist the reader, the complete Table of Contents is included at the beginning of each text volume; appendix volumes include a list of appendixes in the front. Tables and figures for each volume are included at the end of that volume for the sections included in the same volume. The Introduction, EA, FS, and each appendix have separate reference lists.

VOLUME I

- Table of Contents EA/FS - complete Table of Contents for all volumes, followed by List of Tables and List of Figures
- Preface EA/FS - explanation of the organization of the EA/FS report
- Executive Summary - summary of information presented in the EA/FS
- Introduction to the EA/FS - introductory material common to both the EA and the FS, including site history and nature and extent of contamination at the Offpost OU
- Glossary EA/FS - list of acronyms and abbreviations used in the EA/FS

VOLUME II

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Preface EA - outline of the organization of the EA
- Section 1.0 EA - Identification of Chemicals of Potential Concern
- Section 2.0 EA - Exposure Assessment
- Section 3.0 EA - Toxicity Assessment
- Volume II Tables EA - tables for Sections 1.0, 2.0, and 3.0 of the EA
- Volume II Figures EA - figures for Sections 1.0, 2.0, and 3.0 of the EA

VOLUME III

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Section 4.0 EA - Human Risk Characterization

- Section 5.0 EA - Ecological Assessment
- Section 6.0 EA - Conclusions
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- Volume III Tables EA - tables for Sections 4.0, 5.0, and 6.0 of the EA
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- List of EA Appendixes
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VOLUME V

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Preface FS - outline of the organization of the FS
- Section 1.0 FS - Feasibility Study Purpose and Organization
- Section 2.0 FS - Development of Remedial Action Objectives and Screening of Technologies
- Volume V Tables FS - tables for Sections 1.0 and 2.0 of the FS
- Volume V Figures FS - figures for Sections 1.0 and 2.0 of the FS

VOLUME VI

- Table of Contents EA/FS - complete Table of Contents is included in each volume
- Section 3.0 FS - Development of Remedial Alternatives
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- Section 7.0 FS - References
- Volume VI Tables FS - tables for Sections 3.0, 4.0, 5.0, and 6.0 of the FS
- Volume VI Figures FS - figures for Sections 3.0, 4.0, 5.0, and 6.0 of the FS

VOLUME VII

- List of FS Appendixes
- FS Appendixes (A through F) - All Appendixes for the FS

VOLUME VIII

- Response to Comments
- Glossary - list of acronyms used in the responses

EXECUTIVE SUMMARY

This Final Endangerment Assessment/Feasibility Study (EA/FS) is consistent with the National Contingency Plan (NCP), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the regulations implementing the National Environmental Policy Act of 1969 (NEPA), and Federal Facility Agreement (FFA).

ENDANGERMENT ASSESSMENT

An Endangerment Assessment was performed for the Offpost Operable Unit (OU) of Rocky Mountain Arsenal (RMA). The offpost area consists of 27 square miles located to the north and northwest of RMA. The Offpost OU is defined by the Federal Facility Agreement as that portion of the offpost area where the hazardous substances, pollutants, or contaminants from RMA are found, and which is subject to remedial action. On the basis of information existing at the conclusion of the offpost remedial investigation (RI) and the beginning of the FA/FS, the Offpost OU is assumed to be coincident with the offpost area. It is currently characterized by rural agricultural and residential land uses, with some industrial land use. In the future, land use is projected to change to more commercial, industrial, and recreational land use in areas adjacent to RMA, with some areas zoned for residential development (Adams County Planning Commission, 1990). For these reasons, a rural residential scenario (including agriculture), an urban residential scenario (excluding farm animals), and a commercial/industrial scenario were evaluated. An ecological assessment was also performed, due in part to the bald eagle habitat and other sensitive environments in the Offpost OU. The major steps performed in the EA included data evaluation, identification of chemicals of potential concern, exposure assessment, toxicity assessment, human risk characterization, and ecological assessment.

Identification of Chemicals of Potential Concern

Chemicals of potential concern (COCs) were identified by medium. The primary criterion for identification of COCs was a statistically significant increase in concentration in samples collected from the Offpost OU when compared with samples from locations believed to be unaffected by RMA contamination (i.e., background).

The statistical procedures used in this assessment to determine whether chemical concentrations were elevated above background levels contained several conservative elements when compared with procedures recommended by published guidance. These conservative elements were included to compensate for small sample size and low frequency of detection above certified reporting limits in some of the data sets. The conservative features built into the statistical procedure exceeded published guidance and resulted in the inclusion of four groundwater COCs, two surface-water COCs, and one surface soil COC that would normally have been excluded.

Thirty-four COCs were identified for groundwater, including nine pesticides, five inorganic compounds, and 20 volatile or semivolatile organic compounds. Ten COCs were identified for surface water, including four pesticides, two organic compounds, and four inorganic compounds. Each is also a COC for groundwater, the primary source of offpost surface-water contamination.

The six COCs identified in sediments are all pesticides. These COCs are associated with groundwater and/or surface water that interacts with the sediments in First Creek. Six pesticides were identified as COCs in surface soils.

All of the thirty-four COCs were evaluated for biota; however, only those COCs for which a complete pathway of exposure existed for a specific receptor organism were evaluated in the ecological assessment.

Exposure Assessment

The major elements of the exposure assessment included fate and transport of COCs, characterization of the exposure setting and exposure pathways, quantification of exposure, and an uncertainty analysis of calculated exposure intakes.

Chemicals migrated to the Offpost OU as a result of past operations at RMA, primarily by shallow groundwater and airborne pathways. Contaminant transport by both pathways has been controlled by onpost interim remedial actions. Offpost OU surface water was contaminated primarily by the natural interaction with offpost groundwater. Offpost OU surface soil was contaminated by the deposition of airborne contaminants, non-RMA-related intentional agricultural application of pesticides, and irrigation practices. Air monitoring data indicate that the air pathway does not contribute to human exposure.

The COCs exhibit great variability in their mobility and persistence in environmental media. Organochlorine pesticides are relatively immobile and persistent, tending to associate with soils and sediments and tending to bioaccumulate in the food chain; the organochlorine pesticides are the only COCs elevated above background levels in soils and sediments. Most of the remaining COCs are mobile in groundwater, and the aromatics and aliphatics are volatile in surface waters. The fate properties of the COCs tend to determine their distribution in the Offpost OU.

Groundwater containing elevated levels of COCs exists north and northwest of RMA in three distinct plumes with characteristically different groundwater quality conditions. These flow paths are referred to as the northern paleochannel, due north of the RMA north boundary; the First Creek paleochannel, paralleling First Creek to the northwest from the RMA north boundary; and the northwest paleochannel, west of the RMA northwest boundary. The northern and First Creek paleochannels comprise the North Plume Group, and the northwest paleochannel is referred to as the Northwest Plume Group. The alluvial flow system transports most of the contamination in paleochannels characterized by coarser sediments. Groundwater traveling through the First Creek paleochannel discharges to First Creek, probably seasonally, resulting in elevated levels of several COCs in First Creek. First Creek discharges to O'Brian Canal. Concentrations of COCs are reduced substantially upon discharge to O'Brian Canal; only two COCs (diisopropyl methylphosphonate [DIMP] and fluoride) are elevated in the Canal.

Land use in the Offpost OU has been predominantly agricultural and rural residential, with localized commercial/industrial land uses and open space. The portion of the Offpost OU north of O'Brian Canal, where irrigation water is available from Burlington Ditch, contains many vegetable and turf farms. A recent change in land use affecting exposure to COCs was the purchase of former residential properties near the intersection of 96th Avenue and Peoria Street by Shell Oil Company. Based on local planning documents, it is expected that development resulting from encroachment of the Denver suburban fringe from the southwest and the new regional airport to the east will supplant agricultural land uses with residential and commercial/industrial land uses over the next 20 years.

The predominant traditional agricultural land use of the area supports the evaluation of exposure pathways involving consumption of foods produced in the Offpost OU. A complete pathway must have a source, a mechanism of release, a transport medium, an exposure point, a receptor (e.g., humans must be present to be exposed), and an exposure route (e.g., ingestion). The most important pathways considered under the residential reasonable maximum exposure (RME) scenario, including hypothetical future exposure pathways that may not be complete at this time, are direct ingestion of groundwater, inhalation of volatile COCs released from groundwater used for domestic purposes (e.g., showering, cooking), and consumption of vegetables, meat, eggs, and dairy products produced in the Offpost OU. Exposure concentrations in foods were estimated using equilibrium partition models. Predictions by the models were compared to limited site-specific sampling and analytical data, and the model results approximated the limited number of observed concentrations in meat and eggs. Data for milk and vegetables were insufficient to verify the models.

Current and projected future commercial/industrial land uses in zone 5 suggested that exposure pathways consistent with this land use should be evaluated. The most important pathways considered in the RME commercial/industrial scenario are direct ingestion of groundwater and inhalation of volatile COCs from other uses (e.g., showering).

For purposes of the EA, the Offpost OU was subdivided into six geographic zones, each with distinct exposure conditions. Variations in medium-specific exposure concentrations and land and water use were considered in defining these zones, which are shown in Figure ES1. A separate exposure assessment was performed for each zone. Hypothetical future intakes under the RME scenario are greatest in zones 2, 3, and 4, directly north of the RMA north boundary.

Exposure factors used in this EA conformed to U.S. Environmental Protection Agency (EPA) RME guidance wherever applicable factors existed. Where EPA guidance was not available, RME exposure factors were derived for the 90th percentile of the range of the exposure factor. COC intakes were estimated for lifetime, chronic, and acute exposure durations. The lifetime scenario begins at age 0 and extends for 30 years, considering age-dependent body weight, milk consumption, and direct ingestion of soil. Intakes were estimated for children and adult women to address potentially sensitive subpopulations. The child chronic scenario assumes an exposure duration from ages 1 to 9. Children tend to be exposed at greater rates than adults, so the child chronic scenario represents the RME for chronic noncarcinogenic risk assessment. Commercial/industrial intakes were estimated for adult workers with a 25-year duration.

The RME COC intake estimates include hypothetical exposure pathways that have not been complete for several years (i.e., exposure has not occurred by these pathways). For example, previous residents in zones 3 and 4 and current residents in zone 5 have water supplies other than shallow wells. There are no current residents in zones 3 and 4. Therefore, residential intake estimates in these zones are conservative because the pathways do not represent existing exposures.

A limited quantitative uncertainty analysis was performed to evaluate the possible exposure variation among the potentially exposed population. The uncertainty analysis implies that up to 99 percent of a future exposed population would experience intakes less than the RME. Although there are uncertainties in exposure estimates, the EA generally used conservative approaches to limit the potential for underestimating exposures. Thus, it is reasonable to conclude that the RME falls above the 95th percentile of possible exposures and is thus in the range of exposures consistent with the definition of RME. The uncertainty analysis combines uncertainty in defining exposure concentrations (from monitoring data and models) and variability in hypothetical exposures. The uncertainty analysis process demonstrates that most of the variance in intake estimates can be attributed to variability across the population rather than uncertainty in defining the exposure concentrations.

Toxicity Assessment

Available information on the toxic effects of the COCs, emphasizing information pertinent to the evaluation of subchronic and chronic exposures at relatively low intakes, is summarized in the toxicity assessment section of the report. Available reference doses and cancer slope factors published by EPA were used in this EA. When chronic reference doses were unavailable from EPA, they were estimated or identified from other sources, particularly the RMA onpost toxicity assessment contained in the Final Human Health Exposure Assessment (Ebasco, 1990).

Two of the COCs, arsenic and benzene, are known human carcinogens (EPA category A). Ten COCs are probable human carcinogens (EPA category B2). Category B2 chemicals have sufficient evidence that the chemical causes cancer in laboratory animals, but insufficient evidence for cancer in humans. Most of the COCs have the potential for noncarcinogenic effects on the liver (hepatic system), and these chemicals were grouped to evaluate the probability of adverse effects on the liver.

The potential effects of the contaminants on terrestrial wildlife, livestock, terrestrial vegetation, and aquatic organisms were also summarized in the toxicity assessment section of this report. Toxicity reference values for biota were developed, which are intended to represent exposure levels that would result in a low probability of adverse effects on a population of nonhuman receptors, rather than to protect every individual animal. The potential for ecological effects was also evaluated by comparing observed tissue concentrations of COCs in biota samples to maximum allowable tissue concentrations, which are summarized in the toxicity assessment and ecological assessment.

Human Risk Characterization

Additive carcinogenic risks for residential hypothetical future exposures at RME intake levels by zone are highest in zones 2, 3, and 4. These zones are south of O'Brian Canal and within approximately one mile of the RMA north boundary. Based on the uncertainty analysis, the hypothetical risks may be overstated by threefold from intake considerations alone. Future hypothetical cancer risks (assuming pathways are complete and without considering additional remediation) in these zones are estimated to be less than 3×10^{-4}. More than 60 percent of the risk in each of these zones is attributable to category B2 and C human carcinogens. Thus, the risk estimate is critically dependent on the extrapolation of toxicological data from animals to humans.

The largest contributor to total carcinogenic risk is dieldrin. Two toxicological profiles discussing both animal and human data are in Appendix F of the EA (page F-1 and F-112).

In addition to RMA-related sources, dieldrin in surface soils north of O'Brian Canal appears to be associated with agricultural practices in the Offpost OU. The hypothetical carcinogenic risk associated with dieldrin in soil resulting from agricultural practices in zones other than zone 3 and 4 is 4×10^{-5}. In addition, naturally occurring arsenic in groundwater contributes approximately 4.4×10^{-5} risk. Summing these two risks yields a 8×10^{-5} risk that is not attributable to RMA.

More than 95 percent of the residential hypothetical carcinogenic risk in each zone is attributable to the following pathways, listed in order of their contribution to risk:

1. Ingestion of shallow groundwater
2. Consumption of homegrown vegetables
3. Ingestion of locally produced milk
4. Inhalation of volatiles via domestic use of shallow groundwater (e.g., showering, cooking)
5. Ingestion of locally produced eggs
6. Ingestion of locally produced meat

Dermal exposures for all media do not contribute significantly to carcinogenic risk for the residential exposure, nor does incidental ingestion of soil and sediments. The oral exposure route for all media accounts for more than 70 percent of total carcinogenic risk, with the remainder predominantly by inhalation.

Groundwater is the dominant source medium contributing to total carcinogenic risk in zones 2, 3, and 4 accounting for 60 to 80 percent of total risk, depending on the zone. In the remaining zones where groundwater concentrations are lower, soil contributes relatively more to total risk (40 to 50 percent), and soil alone contributes a risk from agricultural practices of approximately 4×10^{-5} in all zones. Groundwater, surface water, and soil may contribute to estimated risks via multiple pathways, specifically those involving food production within the Offpost OU. Groundwater and surface water are assumed to be used for irrigation of vegetable crops and watering of livestock. Each of the food pathways may also accumulate COCs from soil, and these relationships are quantified via the equilibrium partition models.

Hypothetical risks from all carcinogens are added to determine total carcinogenic risk regardless of target organ/system or weight-of-evidence category. The dominant contribution to total carcinogenic risk in all zones is from category B2 and C carcinogens, as previously presented. Carcinogenic risks are also posed by arsenic, a category A human carcinogen.

Hypothetical future noncarcinogenic effects were evaluated for all COCs by calculating a hazard index (HI), which is the estimated intake divided by a reference dose. An HI of greater than 1.0 warrants further evaluation. Children are a potentially sensitive subpopulation in the residential scenario with the largest potential for adverse noncarcinogenic effects, due to higher intakes. Considering the target organ/system potentially affected by each of the COCs, the most probable noncarcinogenic effect would be to the central nervous system (CNS). The maximum hypothetical future additive child chronic HI for CNS toxicants is 4 in zone 4. Hepatic (liver) effects are also a potential, although smaller, risk, with additive chronic HI of 2 in zones 2 and 3.

RME estimates of hypothetical current carcinogenic risks for residential land use are substantially less than future hypothetical risks. No one resides in zones 3 and 4; hence, there is no hypothetical current risk for these zones. Residents in zones 1B and 2 do not use water from the shallow aquifer. Consequently, the domestic use groundwater pathway is not and has not been complete in these zones for several years. Hypothetical current risks in zones 1B and 2 are at least 3 to 4 times lower than the hypothetical future RME estimates.

For the commercial/industrial RME scenario, hypothetical future carcinogenic risks in zone 5 is approximately 3×10^{-5}, with 83 percent of the risk in zone 5 from aldrin, dieldrin, and arsenic. The estimated chronic HIs (liver toxicants) for the commercial/industrial scenario in zone 5 are less than one.

Ecological Assessment

The objective of the ecological assessment was to determine hypothetical adverse affects of COCs on the environment and nonhuman receptors. Two major natural ecosystem types occur in the Offpost OU: terrestrial and aquatic. There is also extensive agricultural use of the area.

Potential hazards to the different ecological components of the Offpost OU were addressed by considering the hazards to terrestrial, aquatic, and agricultural biota separately. Bioaccumulation and direct toxicity endpoints were evaluated for terrestrial and aquatic life. Maximum allowable tissue concentrations (MATCs) were developed to assess risk from tissue residues as a function of bioaccumulation. The predicted tissue concentrations for endrin for the owl and kestrel exceeded the MATC; however, these predicted tissue concentrations are not supported by actual data from lower trophic levels. In addition, exposure concentrations or intakes were compared to acceptable intakes, such as toxicity reference values or reference media concentrations, resulting in a hazard quotient (HQ). The estimated intake of DDE, DDT, aldrin, dieldrin, and endrin for the ecological receptors did not exceed the toxicity reference values. However, an HQ equal to 1 was calculated for the American kestrel for endrin.

The results of the ecological risk characterization indicate that a minimal potential for adverse effects to receptor species in the aquatic and terrestrial foodwebs exist. Species in the agricultural food web are not expected to be at risk because of exposure to the COCs. Plant life, cattle, and chickens will be relatively unaffected based on the results of the risk characterization.

Endangerment Assessment Conclusion

The objectives of the EA were to provide an analysis of risks in the absence of additional remediation (baseline risks) and to provide a basis for determining the need for remedial action at the Offpost OU. The EA for the Offpost OU has identified hypothetical carcinogenic risks that are within the acceptable carcinogenic risks as defined by the revised NCP (EPA, 1990) and the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA, 1991). Hazard indices only exceeded 1.0 in some noncarcinogenic exposure scenarios.

Although these findings indicate that the Offpost OU remedial action is not warranted on a risk basis, site-specific factors suggest that remedial alternatives for the groundwater medium should be considered. Accordingly, a Feasibility Study has been prepared as a companion document to the EA for the Offpost OU.

FEASIBILITY STUDY

Based on the results of the EA, the FS concurrently developed and evaluated a range of remedial alternatives consistent with the NCP. Based on the evaluation presented in this FS, the Army selected a preferred sitewide alternative, which is consistent with CERCLA and the NCP. The FS shows that the preferred sitewide alternative meets the statutory requirements of CERCLA and the NCP. The major steps performed in the FS include development of remedial action objectives (RAOs), development and screening of remedial alternatives, detailed analysis of remaining alternatives, and selection of the preferred sitewide alternative.

Development of Remedial Action Objectives

The development of RAOs consisted of three steps:

- Identification of COCs by medium
- Identification of media of concern
- Identification of exposure pathways.

Six media were evaluated in the remedial investigation (RI) for the Offpost OU: groundwater, soil, surface water, sediment, air, and biota. Each medium was evaluated in the Offpost EA with respect to (1) the nature and extent of contamination and (2) potential exposure pathways and associated risk characterization.

The cumulative Offpost OU hypothetical cancer risk is a maximum of 3×10^{-4} on the basis of the RME risks presented in the EA (Volume III, Section 4.0 and Volume IV, Appendix G). Since the Offpost OU cumulative risk is within the acceptable cancer risk range specified by EPA, Offpost OU remedial action is not warranted. The Army, nevertheless, recognizes that there are site-specific factors that suggest remediation of groundwater is preferable to no-action in the

Offpost OU. Groundwater contributes approximately 75 percent of the total hypothetical risk, and the data available showed exceedances of some MCLs in groundwater. Additionally, substantial progress has been made toward the construction and startup of an offpost groundwater treatment system. Since the remaining media contribute a minor amount of risk to the total, the Army concludes that these media do not require development of remedial action objectives (RAOs). On this basis, groundwater was identified as a medium of concern. Soil, surface water, and sediment were identified as not requiring remediation due to the low risk attributable to these media. Air was not identified as a medium of concern because air monitoring data have indicated air quality within the Offpost OU is not affected by contaminants related to RMA. Biota were not identified as a medium of concern. Direct remediation of biota was not included on the basis that it is not effective except by methods that temporarily eliminate receptor species from the contaminated area. However, protection of biota was addressed through the development of ecological criteria for the protection of species potentially at risk.

Groundwater RAOs specify the attainment of preliminary remediation goals (PRGs) for the identified COCs and exposure pathways. In accordance with the NCP, PRGs were developed considering applicable or relevant and appropriate requirements (ARARs), health-based criteria, factors related to technical limitations (e.g., analytical detection limits), land use, and ecological criteria. Final remediation goals will be determined when the remedy is selected and the Record of Decision is issued.

Groundwater exceedances of PRGs were identified in two plume groups, the North Plume Group and the Northwest Plume Group, an area encompassing approximately 590 acres in the Offpost OU. Groundwater alternatives were developed to address the areas of PRG exceedances.

Development and Screening of Remedial Alternatives

Remedial alternatives for the Offpost OU were developed by (1) identifying the media in which COCs were detected at levels exceeding PRGs, (2) calculating the areas and volumes of media exceeding PRGs, and (3) assembling combinations of representative process options into alternatives representing a range of treatment and containment combinations that address the

RAOs. Consistent with the NCP, a range of alternatives for groundwater was developed from no action to complete removal or destruction of contaminants exceeding PRGs.

Use of Groundwater Modeling in Alternatives Development

To aid in the analysis of groundwater alternatives, two numerical models (North Plume Group and Northwest Plume Group) were prepared to simulate the groundwater flow and dissolved chemical transport in the Offpost OU. Due to the approximate nature of the models, and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Although there are inherent uncertainties in the groundwater model, this is a tool being used by the FS and predicted differences in remediation timeframes are considered with respect to evaluating alternative effectiveness. Simulations of contaminant transport were made corresponding to the No Action alternative and other configurations for both the North and Northwest Plume Groups. Initial conditions were chosen to reflect the contaminant plumes and to reflect contaminant removal at the North Boundary Containment System (NBCS) and Northwest Boundary Containment System (NWBCS) consistent with attainment of Offpost OU PRGs at the boundary systems.

North Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the North Plume Group. The major components of each alternative are also listed.

Alternative No. N-1: No Action

The components are as follows:

- Long-term groundwater monitoring
- Five-year site reviews

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and five-year site reviews, as well as the Army's commitment to provide alternative water (i.e., exposure control) to any identified future users of groundwater exceeding PRGs.

Alternative No. N-2: Continued Operation of the North Boundary Containment System With Improvements as Necessary

The major components are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-3: Land Acquisition and Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. N-4: Interim Response Action A

The major components are as follows:

- Removal of contaminated unconfined groundwater north of the RMA boundary in the First Creek and northern paleochannels, using Interim Response Action (IRA) A groundwater extraction wells
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the unconfined flow system (UFS), using IRA A wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS and IRA A as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-5: Expansion 1 to Interim Response Action A

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 1 of IRA A (additional wells and trenches)
- Treatment of organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-6: Expansion 2 to Interim Response Action A

The major components are as follows:

- Removal of contaminated UFS groundwater north of the RMA boundary in the First Creek and northern paleochannels, using IRA A groundwater extraction wells
- Expansion 2 of IRA A (additional wells and trenches)
- Treatment of the organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Northwest Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the Northwest Plume Group. The major components for each alternative are also listed.

Alternative NW-1: No Action

The major components are as follows:

- Long-term monitoring
- Five-year site review

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and five-year site reviews, as well as the Army's commitment to provide alternative water (i.e., exposure control) to any identified future users of groundwater exceeding PRGs.

Alternative NW-2: Continued Operation of the Northwest Boundary Containment System With Improvements as Necessary

The major components are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. NW-3: Land Acquisition With Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. NW-4: Northwest Plume Groundwater Extraction/Recharge System

The major components are as follows:

- Removal of contaminated UFS groundwater northwest of the RMA boundary, using three groundwater extraction wells
- Treatment of organic COCs present in the groundwater, using carbon adsorption
- Recharge of treated groundwater to the UFS, using five wells
- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring

- Five-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Detailed Analysis of Alternatives

The remaining alternatives (Alternative Nos. N-1, N-2, N-4, N-5, NW-1, and NW-2) were evaluated with respect to the threshold and primary balancing criteria required by the NCP. The criteria are listed below

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Evaluation of the modifying criteria (i.e., the state and community acceptance) is deferred until completion of the state and public comment periods.

A comparative analysis of the remedial alternatives identifying the relative advantages and disadvantages of each alternative was performed. Based on the analysis, a preferred sitewide alternative was selected.

Selection of the Preferred Sitewide Alternative

Using the evaluation of the alternatives with respect to the criteria required by CERCLA and the NCP, the preferred alternative was selected. The preferred sitewide alternative consists of

Alternative No. N-4 (Interim Response Action A) for remediation of groundwater in the North Plume Group and Alternative No. NW-2 (Continued Operation of the NWBCS with Improvements as Necessary) for remediation of groundwater in the Northwest Plume Group.

Redefinition of the Offpost Operable Unit

On the basis of the FS analysis of and selection of the preferred alternative and the Federal Facility Agreement definition of the Offpost OU, the offpost area is not coincident with the Offpost OU. Consistent with the Federal Facility Agreement definition limiting the Offpost OU to that portion of the offpost area where hazardous substances, pollutants, or contaminants from RMA are found at levels subject to remedial action, the Offpost OU is defined as only zones 2, 3, and 4 in the offpost area.

INTRODUCTION TO THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY OFFPOST OPERABLE UNIT

The Final EA/FS report complies with guidelines prepared under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Title 42, United States Code [USC], Sections 9601-9675), the Superfund Amendments and Reauthorization Act of 1986 (SARA), the revised National Contingency Plan (NCP) (Title 40, United States Code (USC) of Federal Regulations [CFR] Part 300), the regulations implementing the National Environmental Policy Act of 1969 (NEPA), and associated U.S. Environmental Protection Agency (EPA) guidance documents.

This introduction provides background information for the Offpost OU including setting, site history and land use, previous investigations, nature and extent of contaminants, and response actions for the Offpost OU.

SETTING

This section describes the site location, environmental setting, geology, and hydrogeology of the Offpost OU.

Site Location

The RMA National Priorities List (NPL) site is comprised of two OUs: Onpost and Offpost. As shown in Figure 1, the offpost area occupies 27 square miles in southern Adams County, Colorado, and lies north of the Denver metropolitan area and east of Commerce City, Colorado. The offpost area is defined as the area southeast of the South Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of RMA, as depicted in Figure 2. The Offpost OU is defined by the Federal Facility Agreement as that portion of the offpost area where hazardous substances, pollutants, or contaminants from RMA are found, and which is subject to remedial action. Additionally, the Offpost OU includes the surface waters of O'Brian Canal and Burlington Ditch as they extend northeast of Second Creek and the surface water of Barr Lake. The Offpost OU encompasses rural residential, agricultural, and commercial/industrial areas located north and northwest of RMA.

Environmental Setting

The topography of the Offpost OU is similar to the topography onpost and consists of stream-valley lowlands separated by gently rolling uplands. The maximum local topographic relief in the area is about 300 feet. The elevation above mean sea level (MSL) ranges from approximately 5330 feet at the southern boundary of RMA to about 5030 at the South Platte River.

Cropland and rangeland provide habitat for numerous animal species, including game species such as cottontails, ring-necked pheasants, and mourning doves. Lake and wetland areas at Barr Lake provide feeding, breeding, and roosting areas for waterfowl and endangered species, including the bald eagle.

The climate of the offpost area is characterized by sunny, semiarid conditions. Approximately 37 percent of the total annual precipitation (16 inches) occurs in the spring, with much of this moisture falling as snow in the early spring. Summer is the hottest season and is characterized by scattered local thunderstorms during afternoons and evenings. Approximately 31 percent of the total annual precipitation occurs during the summer season. Winter is the coldest season, during which time approximately 13 percent of the total annual precipitation occurs.

The regional surface drainage is to the northeast toward the South Platte River. Surface water originating south of RMA, on RMA, or in the Offpost OU flows toward the South Platte River. Two major canals, O'Brian Canal and Burlington Ditch, and several smaller ditches flow from southwest to northeast between RMA and the South Platte River. O'Brian Canal receives some drainage from the Offpost OU and RMA where the canal intercepts First Creek. Burlington Ditch may receive surface water infrequently from First Creek.

Geology

Sediments at the land surface in the Offpost OU consist of unconsolidated alluvial and eolian deposits of Pleistocene and Holocene age. The composition of the unconsolidated sediments varies from clays to coarse gravels, and the thickness varies from less than 10 feet to approximately 100 feet. The thickest deposits of unconsolidated sediments occur in paleochannels eroded into the underlying Denver Formation.

The Denver Formation is of late Cretaceous to early Tertiary age, and consists of 250 to 300 feet of interbedded shale, claystone, siltstone, and sandstone, with a regional dip of one-half to one degree to the southeast. The uppermost bedrock unit was subjected to erosion before deposition of the overlying unconsolidated units. Paleochannels incised into the bedrock surface are present in many areas in the Offpost OU.

The presence of paleochannels in the Denver Formation surface has an impact on groundwater flow in the unconfined flow system (UFS). Two such paleochannels, the First Creek and northern paleochannels, are present north of the RMA North Boundary Containment System (NBCS). An additional paleochannel, the northwest paleochannel, is present west of the RMA Northwest Boundary Containment System (NWBCS). Coarse, unconsolidated materials commonly found within these paleochannels provide for preferential groundwater movement in the UFS. Groundwater contaminant plumes that have historically migrated across the RMA boundaries to the Offpost OU are generally confined to these paleochannels.

The Arapahoe Formation lies beneath the Denver Formation at depths of 230 to 300 feet at the RMA north boundary and has a regional dip of one-half to one degree to the southeast. The formation consists of 400 to 700 feet of interbedded conglomerate, sandstone, siltstone, and shale. The upper portion consists predominantly of 200 to 300 feet blue to gray shale with some conglomerate and sandstone beds. The lower portion consists largely of sandstone and conglomerate with less prevalent beds of shale. The lower portion is a source zone for many water supply wells in the area. The Arapahoe Formation is the oldest geologic unit present beneath the site that was investigated in the Offpost Remedial Investigation (RI) and Offpost RI Addendum programs.

Alluvial and eolian Pleistocene and Holocene deposits form much of the ground surface in the Offpost OU. At some locations, Denver Formation units crop out at the ground surface. The Arapahoe Formation is not present at the ground surface anywhere in the Offpost OU.

Hydrogeology

The two principal water-bearing units in the Offpost OU that have been impacted by chemicals originating from RMA are the unconsolidated alluvial deposits and the underlying Denver Formation. The hydraulic properties of these two units, including hydraulic conductivity, porosity, and associated groundwater flow velocities, are distinctly different. Hydraulically, these two units generally behave as distinct hydrostratigraphic units.

Groundwater flow in the Offpost OU area occurs within an UFS that overlies a confined flow system (CFS). The UFS includes groundwater present in the unconsolidated materials overlying the Denver Formation, the weathered upper portion of the Denver Formation, and, near the South Platte River, the weathered upper portion of the Arapahoe Formation.

The CFS includes the deeper portions of the Denver Formation and the underlying Arapahoe Formation. The Final Water RI (Ebasco, 1989), the Final Offpost RI (ESE, 1988a), and the Draft Final Offpost RI Addendum (Harding Lawson Associates [HLA], 1991a) reports provide further information concerning the conceptual model of groundwater flow in the unconfined and confined flow systems (UFS and CFS). On the basis of an evaluation of the distribution of contaminant plumes in the Offpost OU area, the UFS is considered the principal migration route for groundwater contaminants from onpost to the Offpost OU, although some contaminants are present in the CFS in the Denver Formation and isolated occurrences of a few contaminants have been detected in some domestic Arapahoe Formation wells.

Water-level data for the UFS were collected from all Offpost OU monitoring wells during several monitoring events and programs. The UFS potentiometric surface slopes predominantly toward the northwest, indicating groundwater flow in that direction. This information is consistent with the interpretation that the South Platte River is a regional discharge point for the groundwater system in the Offpost OU. Hydraulic gradients in the Offpost OU range from

0.003 to 0.02 ft/ft and average approximately 0.004 to 0.005 ft/ft. The hydraulic gradients are highest in the area immediately downgradient of the NBCS and in the vicinity of O'Brian Canal and Burlington Ditch.

The hydraulic gradient of the UFS near the canals is consistent with that reported in the Final Offpost RI. However, the hydraulic gradient near the NBCS has increased as a result of the installation and operation of recharge trenches in late 1988. Operation of these trenches has increased groundwater recharge in northern portions of Sections 23 and 24, near the northern RMA boundary.

The confined Denver Formation is heterogeneous and consists of interbedded claystones, siltstones, sandstones, and organic-rich (lignitic) intervals. Water-bearing layers of sandstone and siltstone occur in irregular beds dispersed within thick sequences of relatively impermeable material. Individual sandstone layers commonly are lens-shaped and range in thickness from a few inches to as much as 50 feet. Confined aquifer conditions are observed in sandstone layers within the deeper portions of the Denver Formation.

Water-level data collected from three Arapahoe Formation wells installed under the RI Addendum program indicate that the Arapahoe Formation is a confined aquifer. Data generally indicate that the Arapahoe Formation has a northerly to northwesterly regional groundwater flow direction, as presented in the Final Offpost RI.

SITE HISTORY AND LAND USE

This section presents a discussion of former RMA and Offpost OU activities and land uses.

Former Disposal Practices

RMA began operation in 1942. RMA was a site for the manufacture and demilitarization of chemical and incendiary munitions and the manufacture of industrial chemicals, primarily pesticides and herbicides, until 1984. A detailed account of disposal practices associated with these operations is presented in the Onpost Study Area Reports and RI Media Reports for each potential site.

From 1945 to 1950, RMA distilled available stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired mortar rounds filled with smoke and high explosives. Also, many different types of obsolete World War (WW) II ordnance were destroyed by detonation or burning.

Colorado Fuel and Iron (CF&I) leased facilities at RMA in 1946. Julius Hyman & Company first leased facilities in 1947, and succeeded to the CF&I leasehold interest, with some modifications and additions in 1949. Shell Oil Company acquired a majority interest in Hyman in 1952, and operated the plant as the Julius Hyman Company until 1954, when the operation became the Shell Chemical Company - Denver Plant.

RMA was selected as the site for construction of a facility to produce Sarin, a nerve agent. The facility was completed in 1953, with the manufacturing operation continuing until 1957 and the munitions-filling operations continuing until late 1969. From 1970 until 1984, RMA was involved primarily with the disposal of chemical warfare material. This disposal included the incineration of TX anticrop agent and mustard agent explosive components, and the destruction of Sarin and related munitions casings by caustic neutralization.

Chemicals were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewater to basins, and leakage of wastewater and industrial fluids from chemical and sanitary sewer systems. Munitions were destroyed and disposed of in trenches. Wastewater generated by the Army and private industry in the South Plants and North Plants areas was discharged to a series of unlined evaporation and holding basins (Basins A, B, C, D, and E) and to asphalt-lined Basin F at various times throughout the history of RMA operations.

The primary areas that have contributed to groundwater contamination at RMA include (1) former manufacturing facilities, (2) former waste storage basins, (3) solid waste disposal areas, (4) the chemical sewer system, and (5) locations with in the rail classification yard, and (6) the motor pool area.

Land Use

The current land use within the Offpost OU is predominantly agricultural and rural residential with localized commercial/industrial land uses and open spaces. Areas within the Offpost OU are largely used for rangeland and dryland farming, with some rural residential areas and scattered areas of intensive agricultural use. Certain areas within the Offpost OU are currently zoned and developed for commercial/ industrial activities. Commerce City, which is located west of RMA, is the only urban area in the immediate vicinity of RMA and has recently annexed lands within the Offpost OU. Another geographic feature in the Offpost OU is Barr Lake, a state recreation area.

Farming in the Offpost OU ranges from large grain operations covering square miles to small subsistence farms to vegetable gardens. A number of these farms also maintain livestock. Subsistence and hobby farmers often consume a large part of their diet from locally produced vegetables and livestock produced in the Offpost OU.

Intentional application of pesticides for pest control purposes likely accounts for the presence of some concentrations of pesticides in Offpost OU soil. Many of the pesticides detected in Offpost OU soil are or have been commercially available and may have been applied agriculturally or residentially. These pesticides include cyclodiene compounds and chlorinated hydrocarbon insecticides.

The cyclodiene compounds aldrin, endrin, dieldrin, and isodrin detected in Offpost OU soil have been used as insecticides in areas similar to the Offpost OU from the 1940s to the mid-1970s. Aldrin was used in the early 1950s to protect cotton against boll weevils and in the 1970s for soil application in grain crops and termite control. In Colorado, dieldrin was used to control insects in field vegetable, grain, and fruit crops (Mullins, 1971) and against termites and locusts. Endrin was also used to control a wide range of pests. These insecticides were banned for general uses in 1974 by the EPA. Aldrin and dieldrin may still be used for certain restricted uses such as subsurface insertion for termite control and dipping of nonfood roots.

Evaluation of projected future land use at the Offpost OU indicates that areas of commercial/industrial land use will increase (Adams County Planning Commission, 1987). Rural residential (including agricultural) land use is expected to decrease in the Offpost OU.

PREVIOUS INVESTIGATIONS

As a result of the detection of chemicals in the Offpost OU, the Army initiated a regional sampling of hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from more than 100 onpost and offpost wells and surface-water stations. This program was carried out under the direction of the RMA Contamination Control Program, established in 1974 to ensure compliance with federal and state environmental laws. The objectives of this program were to evaluate the nature and extent of contamination and to develop response actions to control chemical migration. Potential and actual chemical sources were assessed, and chemical migration pathways were evaluated. To minimize offpost discharge of RMA chemicals via groundwater, three boundary containment systems were constructed, one each at the northern, western, and northwestern boundaries of RMA. All three systems are currently in operation to intercept and treat contaminated groundwater and to recharge treated water.

From 1975 to the present, numerous groundwater monitoring programs have been conducted at RMA. The Army designed and implemented the 360 Degree Monitoring Program to monitor regional groundwater and surface water. The Army designed and implemented boundary system monitoring program to support the operation of the boundary control systems. Studies conducted at RMA to assess groundwater and surface-water conditions are discussed below.

The RMA Offpost Contamination Assessment Report (CAR) (ESE, 1987a) incorporated data from several studies to depict the distribution and concentrations of offpost contamination north and northwest of RMA. The scope of this investigation was intended to address critical data gaps required to evaluate a comprehensive set of multimedia exposure pathways. In the mid-1980s, the potential for contamination of private wells was investigated. These were referred to as Consumptive Use (CU) Studies, Phases I, II, and III. The CU Phase I and II studies (ESE, 1985; ESE

1986) addressed the RMA offpost area bounded to the south by East 80th Avenue, to the northwest by the South Platte River, and to the north and east by Second Creek.

In the CU Phase III study (ESE, 1987b), the Army conducted an inventory of privately owned drinking water wells in an area bound by East 80th Avenue on the south, East 96th Avenue on the north, the South Platte River on the west, and RMA on the east. The objectives of the study were as follows:

- Locate all shallow domestic wells (less than 100 feet) in the study area.
- Sample a representative number of the located wells.
- Assess the groundwater quality of the shallow alluvial aquifer.

U.S. Environmental Protection Agency Study Area

In 1981, a random national survey of drinking water systems was conducted by EPA. Several organic chemicals were detected in South Adams County Water and Sanitation District (SACWSD) wells. Additional sampling in 1982 and 1985 confirmed these results. As a result of these findings, EPA began an RI/FS of an area located west of RMA and south of the Offpost OU.

RMA was suspected as one of the potential sources of contaminants in the EPA study area because of the history of waste disposal practices on that site. In response, the Army and EPA built a water supply system for SACWSD. Further investigation by EPA's Field Investigation Team indicated that source areas other than RMA may have been contributing to groundwater contamination detected within the study area. Groundwater monitoring wells installed on the Chemical Sales Company (CSC) property have since confirmed that CSC is a possible source of groundwater contamination west of RMA and south of the Offpost OU.

Comprehensive Monitoring Program

In the mid-1980's, the Program Manager for RMA (PMRMA) developed the Comprehensive Monitoring Program (CMP), a long-term multimedia monitoring program designed to provide data to facilitate evaluation of response actions. Sample collection under the CMP commenced in 1987, and data from the CMP were used in performing this EA/FS.

Scope of the Remedial Investigations

Based on known areas of onpost and offpost contamination and the predominant groundwater and surface-water flow patterns, the Offpost OU for the Offpost RI/FS is the area between north and northwest boundaries of RMA and the South Platte River. The specific boundaries of the unit are the same as for the Offpost CAR, as shown in Figure 2 and described below:

- Southeast boundary - north and northwest boundaries of RMA
- Southwest boundary - 80th Avenue
- West and northwest boundary - South Platte River
- Northeast boundary - Second Creek

The Offpost OU was originally selected on the basis of a conservative estimate of the area with which RMA chemicals may now or may eventually exist. However, based on current knowledge (HLA, 1991a), most of the Offpost OU is not contaminated by chemicals originating from RMA. The surface waters of Barr Lake have also been included in the Offpost OU because of the potential for contaminant migration through surface-water features.

Several sources of trichloroethene have been documented south of the Offpost OU in or near Commerce City. Also, recent investigations by EPA and the Army along the western sections of RMA have detected the presence of a trichloroethene plume entering Township 35, Range 67W, Section 9 along the southern boundary of RMA. Although trichloroethene has been detected in selected dewatering wells of the Irondale system, no trichloroethene has been detected in the influent or effluent sumps of the system. Because of the potential for multiple trichloroethene sources upgradient of the Offpost OU, trichloroethene detected in the area between 80th and 88th Avenues falls under the jurisdiction of EPA.

The primary objectives of the Offpost RI were to:

- Collect additional data to refine the current understanding of groundwater flow and surface-water patterns, and the nature and extent of contaminants offpost of RMA.

- Evaluate the potential for chemical migration to the Offpost OU in various media, such as groundwater, surface water, sediment, air, and biota.
- Provide additional data necessary, to complete the EA/FS.

The review of past studies provided the data to evaluate wells that have been sampled in the past, use results from previous aquifer tests, to analyze historical onpost and offpost contaminant plumes, and to examine and develop an overall geologic and hydrologic understanding of the Offpost OU. Additionally, biota and air quality information for the Offpost OU were reviewed and used to assess the human and environmental receptors that may be at risk and to define airborne pollutant pathways.

As a result of the review of the past programs and the original Offpost RI program, limitations to the groundwater, soil, surface water, sediment, and biota databases were identified, and appropriate sampling and analysis were completed in the RI Addendum (HLA, 1991g) program. Data collection consisted of compiling new hydrogeologic and chemical data relevant to the Offpost OU. Data were obtained by drilling new wells and borings, collecting groundwater and surface-water samplers for analysis, measuring groundwater levels and surface-water flows, conducting aquifer tests, and obtaining sediment samples for analysis.

Surface-water and sediment samples were collected in the Offpost OU to define chemicals in the media. Samples were collected from streams, creeks, impoundments, and lakes that were suspected pathways for migration of onpost contamination to the Offpost OU. The data were used to evaluate contamination in surface water and sediment as well as to evaluate surface water and groundwater interaction.

Biota and air-quality condition were evaluated using onpost and offpost information collected during past and current studies. Input from the Offpost CAR was used to assess transport of chemicals and impacts on biota in the Offpost OU from onpost conditions. Data from the Air RI Report (ESE, 1988b) were used to assess the potential for migration of airborne chemicals to the Offpost OU.

The water, sediment, biota, and air quality information was organized so that a comprehensive evaluation of RMA chemicals in all media could be made in the Offpost OU. The information collected during the Offpost RI and RI Addendum was integrated with historical data as well as data being collected during other ongoing RMA investigations.

In general, the RI Addendum summarizes new information primarily pertaining to further assessment of the extent of contamination in various media (groundwater, soil, surface water, sediment, and biota) within specific geographic areas. Activities performed in preparation of the RI Addendum include a review of existing data and collection and interpretation of additional field data to address identified data needs.

NATURE AND EXTENT OF CONTAMINATION

This section discusses the nature and extent of contaminants in the groundwater, soil, surface water, sediment, and air media in the Offpost OU as currently understood. The Offpost RI and RI Addendum reports were the primary sources of information for the groundwater, soil, surface water, sediment, and biota media. Another source of information for the groundwater medium was CMP annual groundwater data. The primary source of information on the air medium was the CMP Air Quality Data Assessment Report for 1989 (RLSA, 1990). In determining COCs and exposure point concentrations, the EA used environmental data for the period 1985 to 1991 including these reports.

Groundwater - Semivolatile Organic Compounds

This section provides a summary of the nature and extent of contamination in groundwater in the Offpost OU on the basis of groundwater occurrence in both the UFS and CFS. Diisopropylmethylphosphonate (DIMP), dicyclopentadiene, dieldrin, and endrin are the most widespread and consistently detected semivolatile organic compounds (SVOCs) in groundwater in the Offpost OU of these chemicals.

The most widespread contaminant detected in groundwater in the Offpost OU is DIMP. As Figure 3 illustrates, DIMP is distributed in a continuous plume extending from the RMA north and northwest boundaries to the South Platte River. Samples from 89 monitoring wells were analyzed for DIMP, which DIMP was above the CRL in 71 of these samples. In general, the highest concentrations of DIMP offpost occur between the RMA northern boundary and the O'Brian Canal. The highest observed concentrations were 5800 micrograms per liter ($\mu g/l$) in the First Creek paleochannel, 860 $\mu g/l$ in the northern paleochannel, and 80 $\mu g/l$ in the northwest paleochannel.

Current data indicate the distribution of dicyclopentadiene, as shown in Figure 4, is generally limited to the First Creek paleochannel. The maximum concentrations of dicyclopentadiene reported in the Offpost RI Addendum was 600 $\mu g/l$.

The distribution of dieldrin is shown in Figure 5. Dieldrin occurs in the Offpost OU north of the northern and northwestern RMA boundaries. The highest concentrations of dieldrin are found in wells located in the First Creek paleochannel, ranging from 0.6 to 0.9 $\mu g/l$. Dieldrin plumes are also interpreted in limited areas in the northern paleochannel and in two areas north of the northwestern RMA boundary. Detectable concentrations of dieldrin in the northern paleochannel and northwestern paleochannel ranged from 0.05 to 0.14 $\mu g/l$.

The distribution of endrin is shown in Figure 6. The highest concentrations of endrin ranged from approximately 0.25 to 0.75 $\mu g/l$ for wells immediately north of the northern RMA boundary. The maximum concentration of endrin was 0.748 $\mu g/l$ from well 37309, located approximately 1500 feet north of RMA. Endrin was also detected in groundwater samples collected from wells in the central portion of the northern paleochannel.

Other SVOCs were detected in groundwater samples from the Offpost OU. The other SVOCs detected include the pesticides atrazine, malathion, and parathion; the organsulfur compounds 4-chlorophenylmethyl sulfone ($CPMSO_2$) and 4-chlorophenylmethyl sulfoxide (CPMSO); and the organchlorine pesticides aldrin, isodrin, chlordane, 2,2-bis (para-chlorophenyl)-1,1-dichloroethene (DDE), and 2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane (DDT).

The distribution of atrazine in the Offpost OU is similar to that of the organochlorine pesticides (OCPs). Atrazine was detected in 21 Offpost OU wells, with the maximum concentrations occurring in the First Creek (46.0 $\mu g/l$) and northern (72.9 $\mu g/l$) paleochannels. Atrazine was generally not detected in groundwater samples collected from the Offpost OU off the northwestern RMA boundary, except for two isolated occurrences.

Although CPMSO and $CPMSO_2$ are both organosulfur compounds, their distributions in offpost groundwater differ. CPMSO was generally only found in samples collected from wells installed in the northern paleochannel, whereas $CPMSO_2$ was generally only found in samples collected from wells located in the First Creek paleochannel. CPMSO was generally found at levels higher than those reported for $CPMSO_2$. CPMSO was detected at concentrations up to 82.2 $\mu g/l$ in the northern paleochannel. $CPMSO_2$ was also detected in the First Creek paleochannel at concentrations up to 21.0 $\mu g/l$.

The distribution of the additional OCPs (aldrin, isodrin, chlordane, DDE, and DDT) is similar to the previously discussed distribution of the OCPs dieldrin and endrin. The maximum concentrations of these compounds generally occur in the First Creek paleochannel, usually in the area 500 to 1000 feet north of the NBCS. Generally, only sporadic, isolated occurrences of these compounds were observed in the Offpost OU north of the RMA northwestern boundary.

Groundwater - Volatile Organic Compounds

The volatile organic compounds (VOC) most frequently detected in the Offpost OU include chloroform, chlorobenzene, dibromochloropropane, tetrachloroethene, trichloroethene, 1,2-dichloroethene, carbon tetrachloride, and benzene.

Chloroform occurs primarily downgradient of the NWBCS and in the northern paleochannel, as shown in Figure 7. Chloroform was generally not found in the First Creek paleochannel. Concentrations of chloroform emanating from the northern RMA boundary are higher than concentrations in the Offpost OU north of the northwestern RMA boundary. The highest concentrations of chloroform occur at the north end of the northern paleochannel (200 to 400 $\mu g/l$). The highest concentration of chloroform was 19.8 $\mu g/l$ in the northwestern palecchannel.

The distribution of chlorobenzene is presented in Figure 8. The plumes are confined to localized portions of the First Creek and northern paleochannels. The maximum concentration of chlorobenzene was 38.2 $\mu g/l$ in a groundwater sample collected from a well located in the northern paleochannel approximately one mile north of RMA. The maximum reported concentration in the First Creek paleochannel is less than 2 $\mu g/l$.

The distribution of dibromochloropropane is shown in Figure 9. As shown in Figure 9, dibromochloropropane was generally only found in samples from wells in the northern paleochannel. A few isolated occurrences of dibromochloropropane were observed in the First Creek paleochannel and immediately downgradient of the O'Brian Canal near the northern end of the northern paleochannel. The maximum concentrations of dibromochloropropane ranged from approximately 2 to 7 $\mu g/l$ in a few wells located in the northern paleochannel. All other detectable levels of dibromochloropropane were less than 1 $\mu g/l$.

The distribution of trichloroethene and tetrachloroethene is presented in Figures 10 and 11, respectively. These VOCs are found in the First Creek and northern paleochannels. The highest concentrations of these compounds were detected in samples collected from wells located at the northern end of the northern paleochannel. The concentrations of tetrachloroethene are higher than those reported for trichloroethene. The maximum concentrations of tetrachloroethene were approximately 100 $\mu g/l$ in two wells located in the northern paleochannel, approximately one-mile north of the RMA boundary. The highest concentrations of trichloroethene in the Offpost OU north of RMA ranged from approximately 5 to 7 $\mu g/l$.

Other volatile organic compounds (VOCs) detected in the Offpost OU include benzene, carbon tetrachloride, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,2-dichloroethene, toluene, and xylenes. These compounds were generally found in only a few groundwater samples collected from wells installed in the UFS.

Groundwater - Inorganic Compounds

This section describes the distribution of selected inorganic constituents in groundwater. The inorganics presented below include arsenic, chloride, fluoride, and mercury.

The distribution of arsenic based on data collected in support of the Offpost RI Addendum and for the CMP, is shown in Figure 12. As shown in Figure 12, the distribution of arsenic is sporadic, with detectable levels of arsenic occurring in a number of areas. Arsenic occurs in a plume along the First Creek paleochannel. The maximum concentrations of arsenic in the Offpost OU are 4 to 5 $\mu g/l$.

The distribution of chloride is shown in Figure 13. Chloride occurs in plumes in the Offpost OU north of the northern and northwestern RMA boundaries. Chloride concentrations in the First Creek and northern paleochannels generally exceed 250,000 $\mu g/l$. The maximum concentrations of chloride occur in the First Creek paleochannel. Offpost of the northwestern RMA boundary, chloride concentrations exceeding 250,000 $\mu g/l$ occur immediately downgradient of the RMA boundary. Concentrations of chloride below 50,000 $\mu g/l$ occur only in limited areas (Figure 13).

The distribution of fluoride is presented in Figure 14. Fluoride concentrations generally exceed 3000 $\mu g/l$ in the First Creek paleochannel and 2200 $\mu g/l$ in the northern paleochannel. Concentrations average approximately 2000 $\mu g/l$ in the northwestern paleochannel.

The Final Offpost RI reported mercury in only one offpost groundwater sample. The sample, which was collected from well 37342 located in the First Creek paleochannel, had a mercury concentration of 0.36 $\mu g/l$. Data generated during Offpost RI Addendum activities showed detectable levels of mercury in four samples collected from wells located 2000 to 7000 feet offpost of the northwestern RMA boundary. Mercury concentrations in these wells ranged from 0.210 $\mu g/l$ to 1.64 $\mu g/l$. The distribution of these sampling locations does not suggest a mercury plume in the Offpost OU, and detections are considered sporadic. Additionally, data collected under the Fall 1989 CMP show a higher frequency of detection for mercury than reported in the Final Offpost RI. The FY90 CMP reported that field or laboratory contamination existed for those mercury results. Thus, data for mercury are considered questionable and not representative of actual groundwater conditions.

Nature and Extent of Confined Denver Formation Contamination

The nature and extent of the confined Arapahoe formation was evaluated through a sampling program of domestic and monitoring wells. The data and interpretations presented in this section are for groundwater samples collected from 14 offpost confined Denver Formation wells in the Offpost OU. Figure 15 presents the locations of these wells. Additional information concerning the confined Denver Formation groundwater is presented in Section 3.3.2 of the Final Offpost RI report.

Data were examined from the Fall 1989 and Spring 1991 CMP sampling rounds, which represent the two most recent sampling rounds. The data reported detections of the following organic compounds: benzene, chlorobenzene, chloroform, DIMP, dibromochloropropane, phenol, and 1,1,1-trichloroethane. The most frequently detected compounds were DIMP, chloroform, and chlorobenzene. In general, the detections were not consistent from one sampling event to the next for the same well. DIMP was detected most frequently; however, detections occurred in only 11 sampling events out of 42 sampling events. The concentrations of DIMP ranged from 0.443 $\mu g/l$ to 46.0 $\mu g/l$. Chloroform and chlorobenzene detection frequencies were below 10 percent. Chloroform concentrations ranged from 0.631 $\mu g/l$ to 1.30 $\mu g/l$. Chlorobenzene detections ranged from 1.10 $\mu g/l$ to 51.5 $\mu g/l$.

The observed detections indicate sporadic, isolated low-level occurrences of these compounds in the Offpost OU in the confined Denver Formation. The data are not consistent temporally for the same well and do not indicate a spatial or areal trend indicative of a contaminant plume.

Nature and Extent of Confined Arapahoe Formation Contamination

The nature and extent of the confined Arapahoe formation was evaluated through a sampling program of domestic and monitoring wells. Two isolated detections of DIMP and one of chloroform were observed in approximately 30 Arapahoe Formation wells sampled by the Army. The detections do not appear to be representative of overall aquifer conditions. For example, the majority of samples collected from Arapahoe Formation wells did not contain detectable concentrations of organic compounds. In addition, DIMP and chloroform were not detected consistently from one sampling event to the next.

Surface Soil

This section presents the concentrations and distributions of compounds detected in soil in the Offpost OU. Surface soil includes the upper 2 inches of the soil profile. As shown in Figure 16, the organochlorine pesticides (OCPs) DDT, DDE, aldrin, chlordane, dieldrin, endrin, hexachlorocyclopentadiene, and isodrin were detected above Certified Reporting Limits (CRLs) in surficial soil collected in the Offpost OU. The most widespread and frequently detected OCP was dieldrin. Concentrations of dieldrin detected in samples in the Offpost OU ranged from 2.05 to 250 micrograms per kilogram ($\mu g/kg$). DDT, aldrin, endrin, and DDE were also frequently detected, generally in samples where dieldrin was also detected.

Offpost OU suface soil was contaminated by the deposition of airborne contaminants and non-RMA-related intentional agricultural application of pesticides and irrigation practices.

The greatest number of compounds and highest concentrations were observed north of RMA, with a few occurrences to the east and west of RMA. Several reasons may, in part, explain the presence of these compounds north and west of the canals: (1) several of the compounds detected in the surficial soil are or have been available commercially and may have been applied agriculturally or residentially and (2) some areas where samples were collected may have been previously irrigated with surface water and/or groundwater originating from RMA.

Arsenic was detected in approximately 20 percent of the samples at concentrations ranging from 2.61 to 4.52 micrograms per gram ($\mu g/g$). The distribution of arsenic was limited to the following detection areas:

- East of RMA
- Immediately north of RMA
- West of the northwest boundary
- Along Burlington Ditch

No identifiable pattern to the distribution is evident.

Mercury was detected in approximately 10 percent of the samples at concentrations ranging from 0.0719 μg/g to 0.325 μg/g. A discernable pattern to the distribution of mercury is not evident.

The concentrations of arsenic and mercury in soil were not statistically evaluated above background as presented in the Offpost EA (Volume II, Section 1.0).

Subsurface Soil

Six subsurface soil samples were collected in the 96th Avenue residential area and analyzed for OCPs, arsenic, and mercury. Subsurface soil samples were collected from approximately 1-foot and 5-foot depths. Only one detection of OCPs was reported in subsurface soil samples. Dieldrin was detected at a concentration of 7.0 μg/kg in a sample collected between 0 and 1 foot. Arsenic was detected above the CRL in one subsurface soil sample at a concentration of 3.59 μg/g in a sample collected between 0 and 1 foot. Mercury was not detected above the CRL in any subsurface soil samples.

Surface Water

Figure 17 presents the distribution of organic contaminants detected in Offpost OU surface water as presented in the Offpost RI Addendum. The concentrations of organic compounds detected in offpost surface-water samples typically have been highest in First Creek near the O'Brian Canal.

DIMP was the organic compound most frequently detected in surface water in the Offpost OU. DIMP was also the most widely distributed compound and was detected in surface-water samples collected from First Creek, O'Brian Canal, and Burlington Ditch at concentrations ranging from 0.532 μg/l to 59.0 μg/l.

The greatest number and highest concentrations of detected OCPs occur in the reach of First Creek between the northern RMA boundary and the confluence with O'Brian Canal.

The maximum detections of arsenic and several other inorganic constituents including chloride and sulfate were found in samples collected from First Creek along the reach between the RMA boundary and the First Creek confluence with O'Brian Canal. Arsenic was detected at concentrations ranging from 2.78 to 280 μg/l in Offpost RI Addendum samples. The concentration of 280 μg/l is considered anomalous and not representative of surface-water quality in the Offpost OU. The maximum concentrations of arsenic are commonly found in surface-water samples collected from First Creek immediately downstream of the onpost sewage treatment plant. Arsenic concentrations of approximately 70 μg/l have been detected at this location (RSLA, 1990).

Groundwater and surface-water interaction is known to occur in the reach of First Creek between the northern RMA boundary and the confluence of First Creek with O'Brian Canal. This interaction has been discussed and documented in the Final Offpost RI and FY90 Surface Water CMP. Comparison of the concentrations of organic compounds detected in surface-water samples with those detected in groundwater samples collected in the vicinity of this reach of First Creek supports the conclusion that contaminated groundwater discharging into First Creek may be the source of organic contamination in surface water. The decrease in number and concentrations of organic compounds in Burlington Ditch and the O'Brian Canal indicates that dilution of surface water by the ditch and canal is occurring. The distribution of arsenic in offpost surface water suggests a source other than groundwater. A potential source appears to be onpost Sewage Treatment Plant discharge to First Creek.

Sediment

Figure 18 presents the distribution of organic contaminants detected in sediment as presented in the Offpost RI Addendum. The following organic compounds had the highest frequency of detection in sediment samples in the Offpost OU: aldrin, chlordane, dieldrin, and dibromochloropropane. The detections were predominantly in samples collected from in First Creek and were generally low concentrations.

Arsenic and mercury were detected at low concentration levels in sediment samples in the Offpost OU. Mercury was detected only in the Burlington Ditch, O'Brian Canal, and Barr Lake samples. Arsenic was detected in sediment samples in the Offpost OU from all water bodies sampled.

Air

Results from onpost RMA air monitoring during 1988 and reported in the CMP Air Quality Data Assessment Report (R.L. Stollar & Associates, 1990) (FY88 Air CMP) indicated that total suspended particulate (TSP) levels at RMA boundaries were below the levels of metropolitan Denver. Asbestos was monitored but not detected. VOCs measured at RMA boundaries appear to present toxic risks similar to those encountered in the urban environment of metropolitan Denver. Levels of SVOCs were detected at negligible and/or regional baseline levels at RMA boundaries. Metal levels were proportional to TSP concentrations and were not elevated.

GROUNDWATER TREATMENT SYSTEMS THAT AFFECT THE OFFPOST OPERABLE UNIT

Three major containment/treatment systems, the Irondale Containment System (ICS), the NBCS, and the NWBCS, have been installed at the RMA boundaries to control the migration of contaminants to offpost areas. All three of the systems are currently in operation to intercept and treat contaminated groundwater and to recharge the treated water. In addition to the boundary control systems, a groundwater intercept and treatment system north of RMA (Groundwater Intercept and Treatment System North of RMA Interim Response Action A [IRA A]) is currently being constructed to provide remediation of alluvial groundwater in the Offpost OU.

Irondale Containment System

The ICS is located at the southern end of the RMA northwest boundary within Section 33 and consists of a hydraulic control system and a carbon treatment system. The ICS became operational in 1981. The majority of the area downgradient of the ICS is contained within the EPA offpost study area, although portions of the downgradient area are within the confines of the

Northwest Boundary Containment System

The NWBCS is located along the northwest boundary of RMA in the southeast quarter of Section 22. Construction of the NWBCS began in 1983, and the system became operational in 1984. The purpose of this system was to intercept and remove dibromochloropropane and other organic compounds from a plume of contaminated groundwater originating onpost.

Contaminant bypass was observed at the northeast end of the system in 1988. Recharge was increased at the northeast end in December 1988 to prevent continued contaminant bypass. The system consists of a line of 15 upgradient dewatering wells, a soil bentonite barrier extending approximately two-thirds of the length of the dewatering system, 21 downgradient recharge wells, and a carbon-adsorption treatment facility. Groundwater is pumped from the dewatering wells on the upgradient side of the barrier, treated by carbon adsorption, and returned to the aquifer through recharge wells near the RMA boundary.

An IRA to improve the NWBCS was initiated in 1989. In April 1990, the NWBCS Improvements IRA B(ii) was divided into two phases: NWBCS Short-Term Improvements IRA and NWBCS Long-Term Improvements IRA. The long-term improvements involve a more thorough assessment of the NWBCS and the short-term improvements.

Under the NWBCS Short-Term Improvements IRA, the existing groundwater intercept system was extended both to the southwest and northeast. The soil-bentonite wall was extended across the alluvial channel found northeast of the system to prevent contaminant bypass. Additional extraction wells were added to the existing system to intercept and treat the water in this channel. The northeast extension was completed in July 1990, and recharge rates at the northeast end of the system were reduced. Higher recharge rates resumed in July 1991 at the northeast end of the system. New extraction wells and recharge wells were added to the southwest end of the system and became operational in August 1991.

Interim Response Action A

IRA A addresses contaminant migration north of RMA along two primary contaminant pathways, defined by the First Creek and northern paleochannels.

In the area north of the RMA north boundary, IRA A is being implemented for remediation of contamination in alluvial groundwater in the First Creek and northern paleochannels. The system has been designed to intercept and extract contaminated groundwater from the UFS in each paleochannel, treat the organic fraction of the groundwater, and recharge treated water to the UFS. Groundwater extraction will be achieved by installing and operating well systems. Water will be treated using a granular activated carbon adsorption system and will be recharged to the UFS using a combination of wells and trenches.

The IRA was designed to be flexible to be compatible with the final remedy. Compatibility with the final remedy could be achieved by modifying the system to include the addition of new wells, treatment processes, or additional treatment capacity if necessary. Construction of IRA A began in November 1991.

The groundwater treatment system for IRA A is designed to treat a maximum flow of 720 gpm and an average initial flow of 480 gpm; however, the facilities will be able to accommodate flows less than the average, with a minimum flow of 200 gpm.

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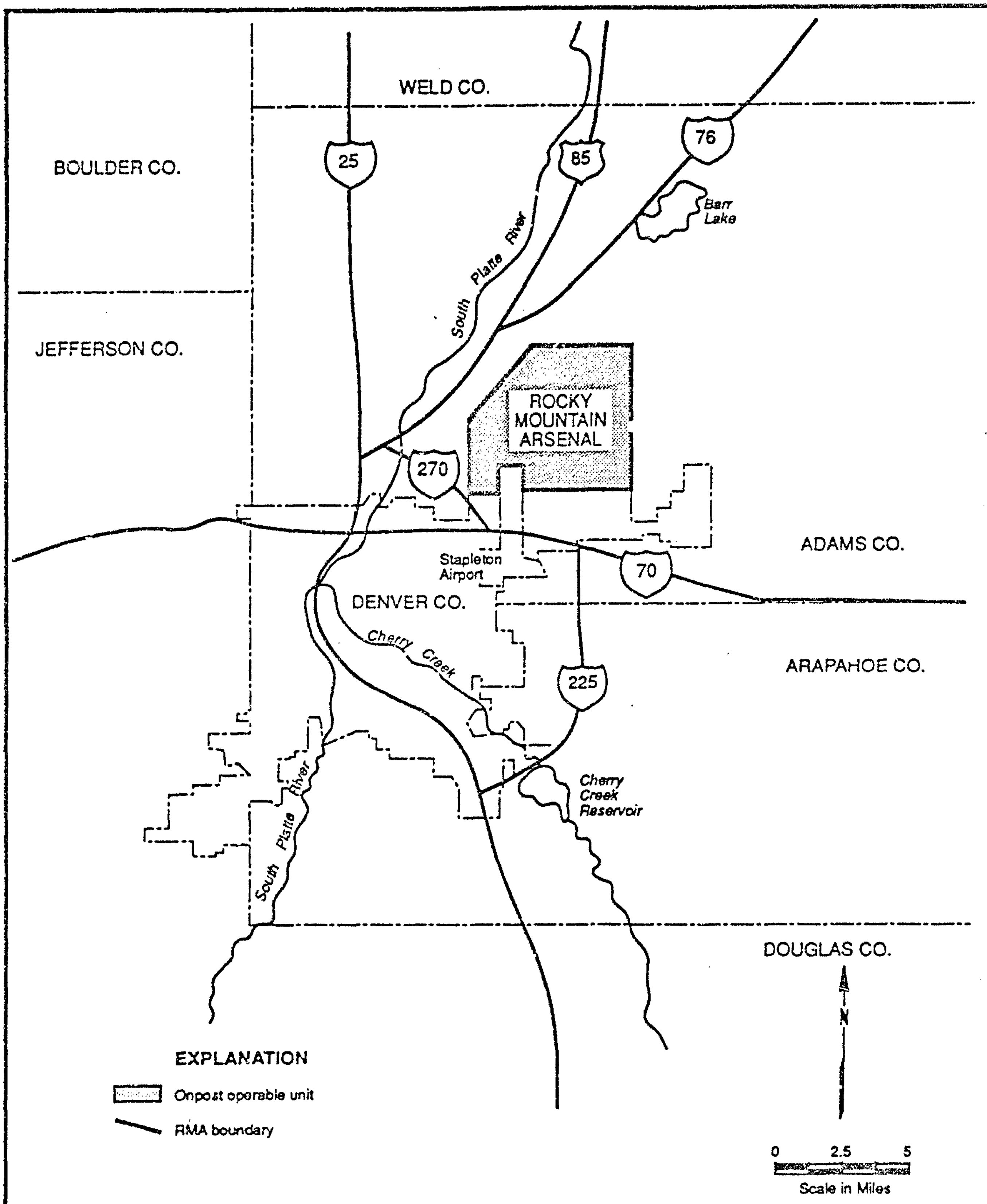
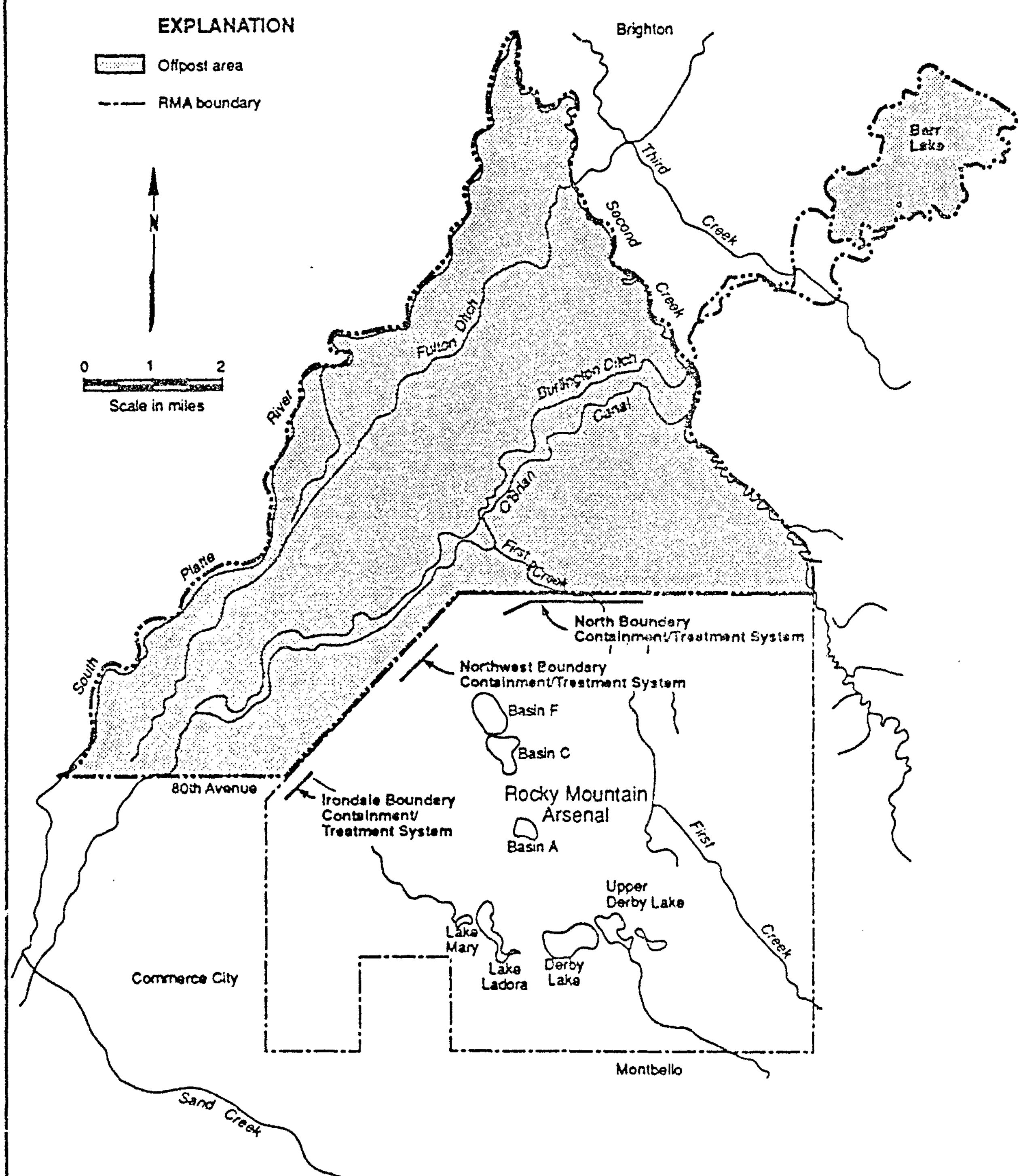
RMA1 1104



Prepared for: **Program Manager for Rocky Mountain Arsenal** Commerce City, Colorado	Figure 1 LOCATION MAP OF ONPOST OPERABLE UNIT, ROCKY MOUNTAIN ARSENAL

RMA1 1101.1



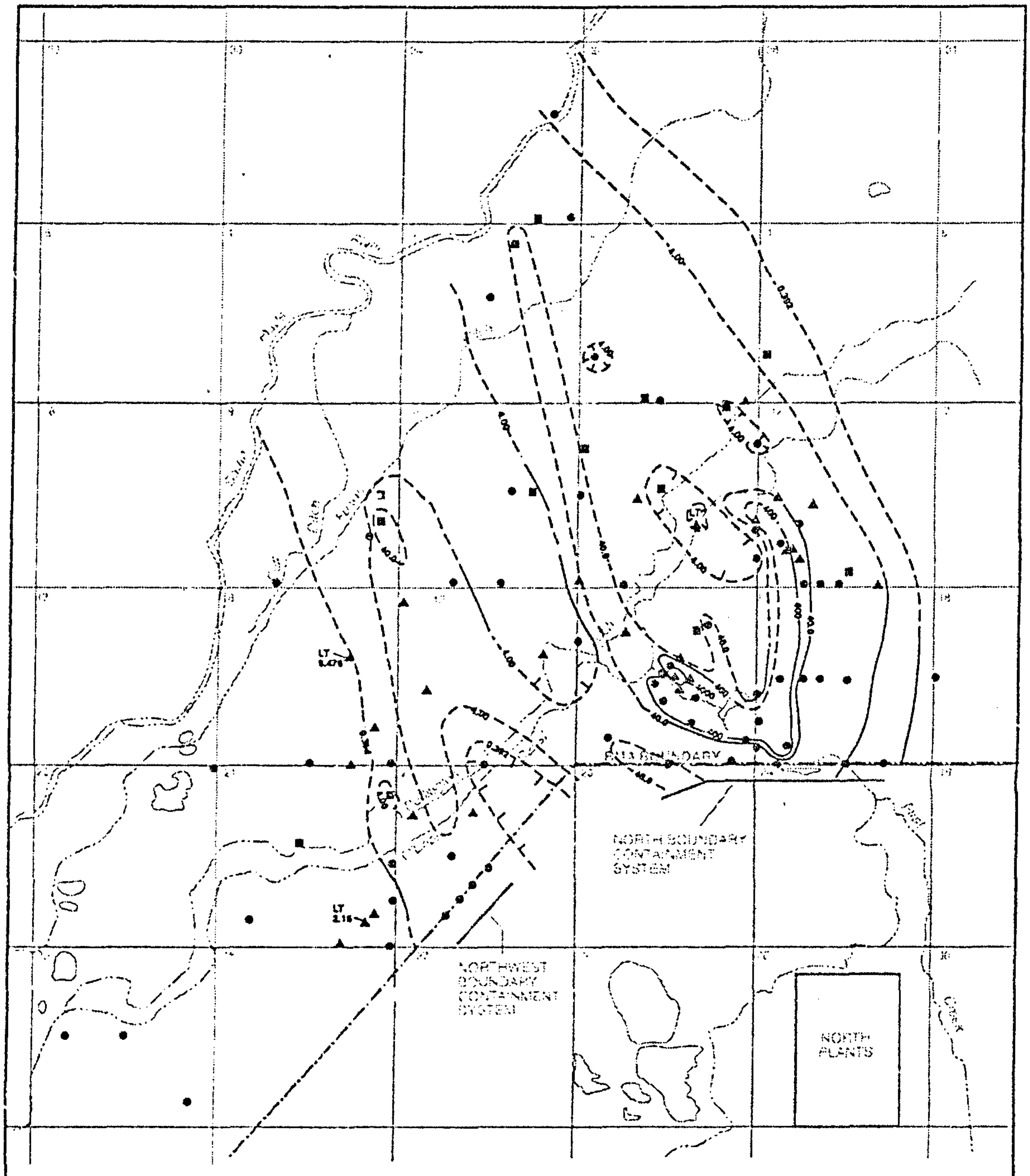
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 2

OFFPOST AREA,
ROCKY MOUNTAIN ARSENAL

RMA1 1144



N

0 1500 3000

Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.392
4.00
40.0
400
4000

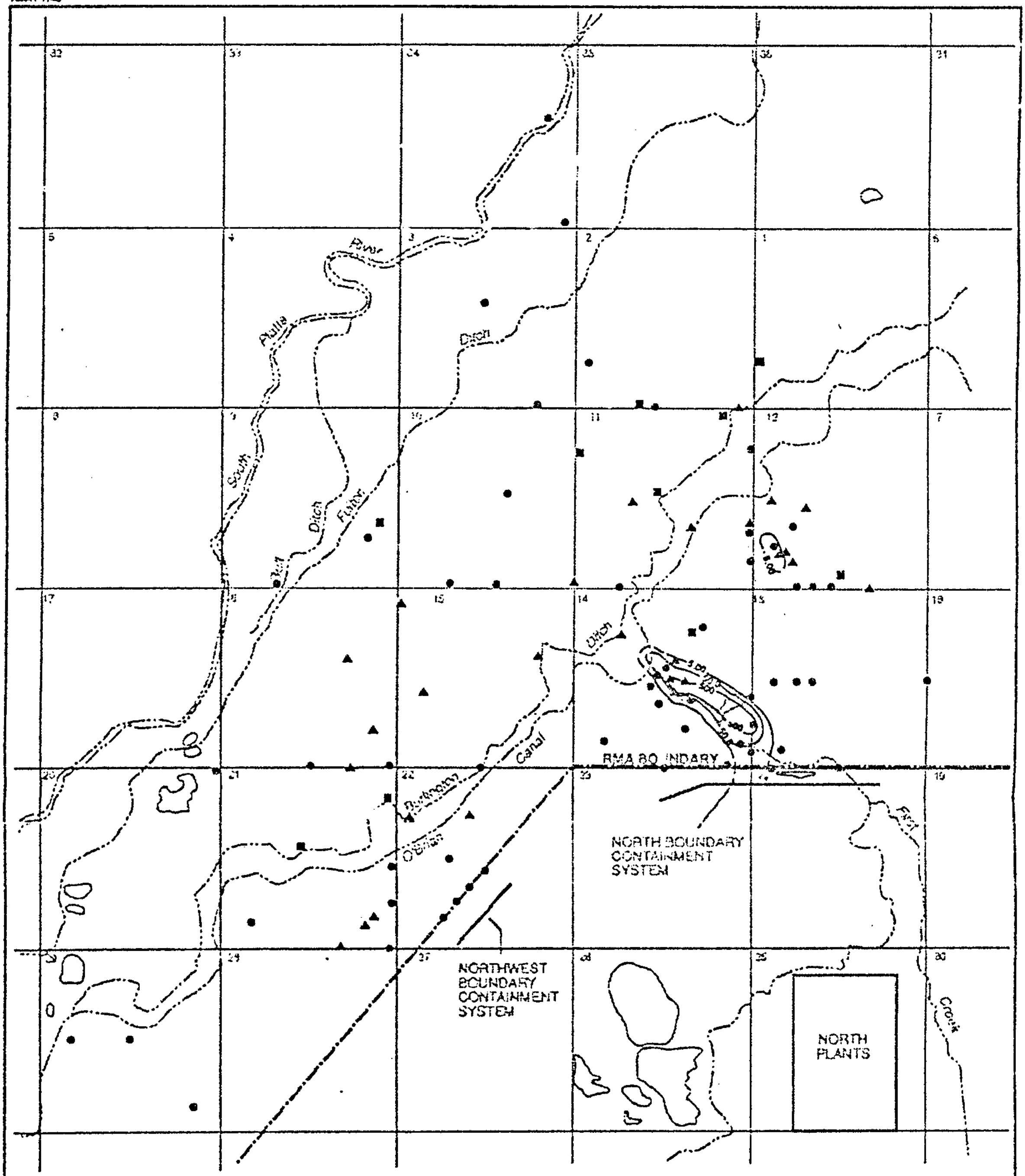
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 3

DISTRIBUTION OF DIISOPROPYLMETHYL PHOSPHONATE (DIMP) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1145



N

0 1500 3000

Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.85 Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

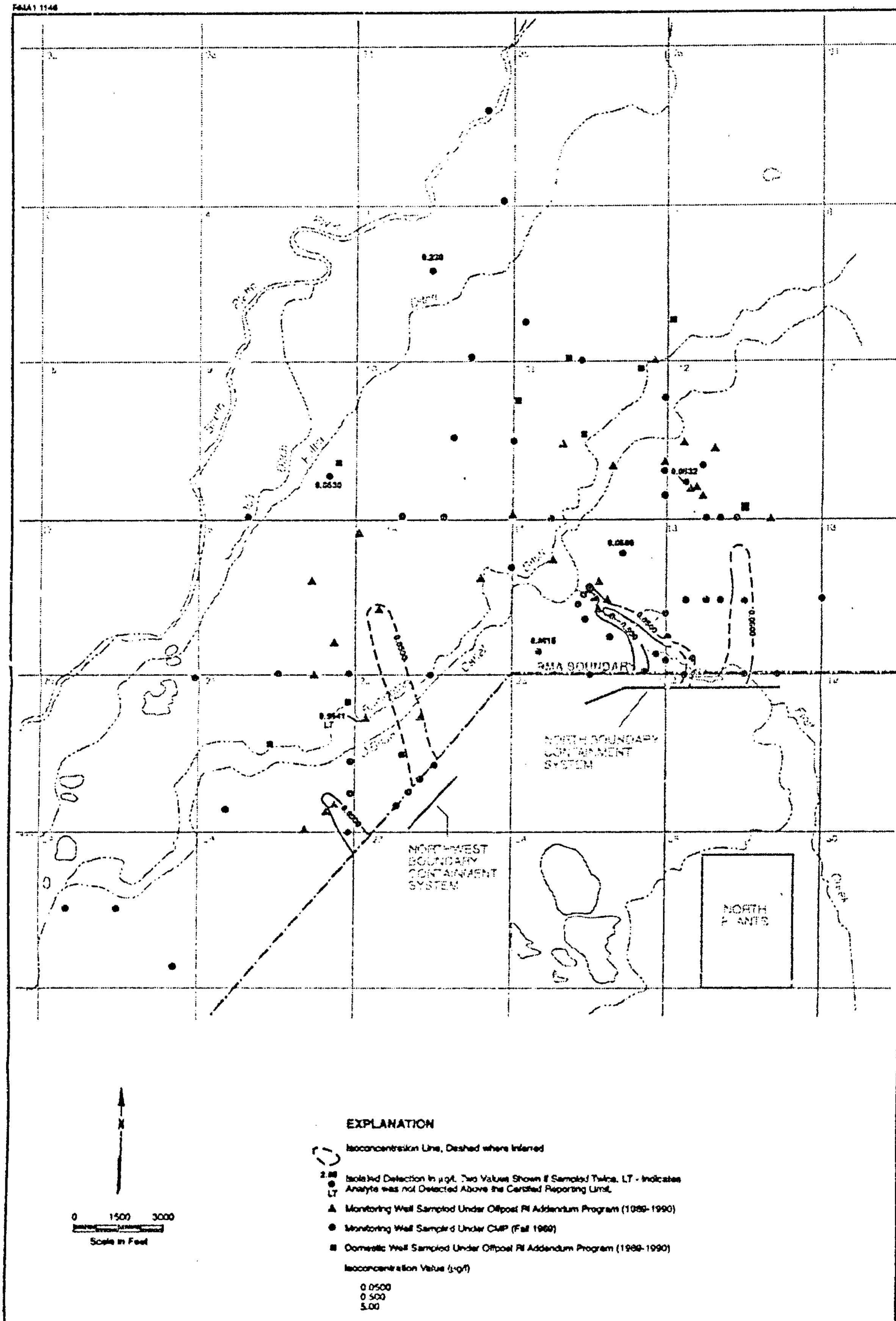
■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

5.00
50.0
500

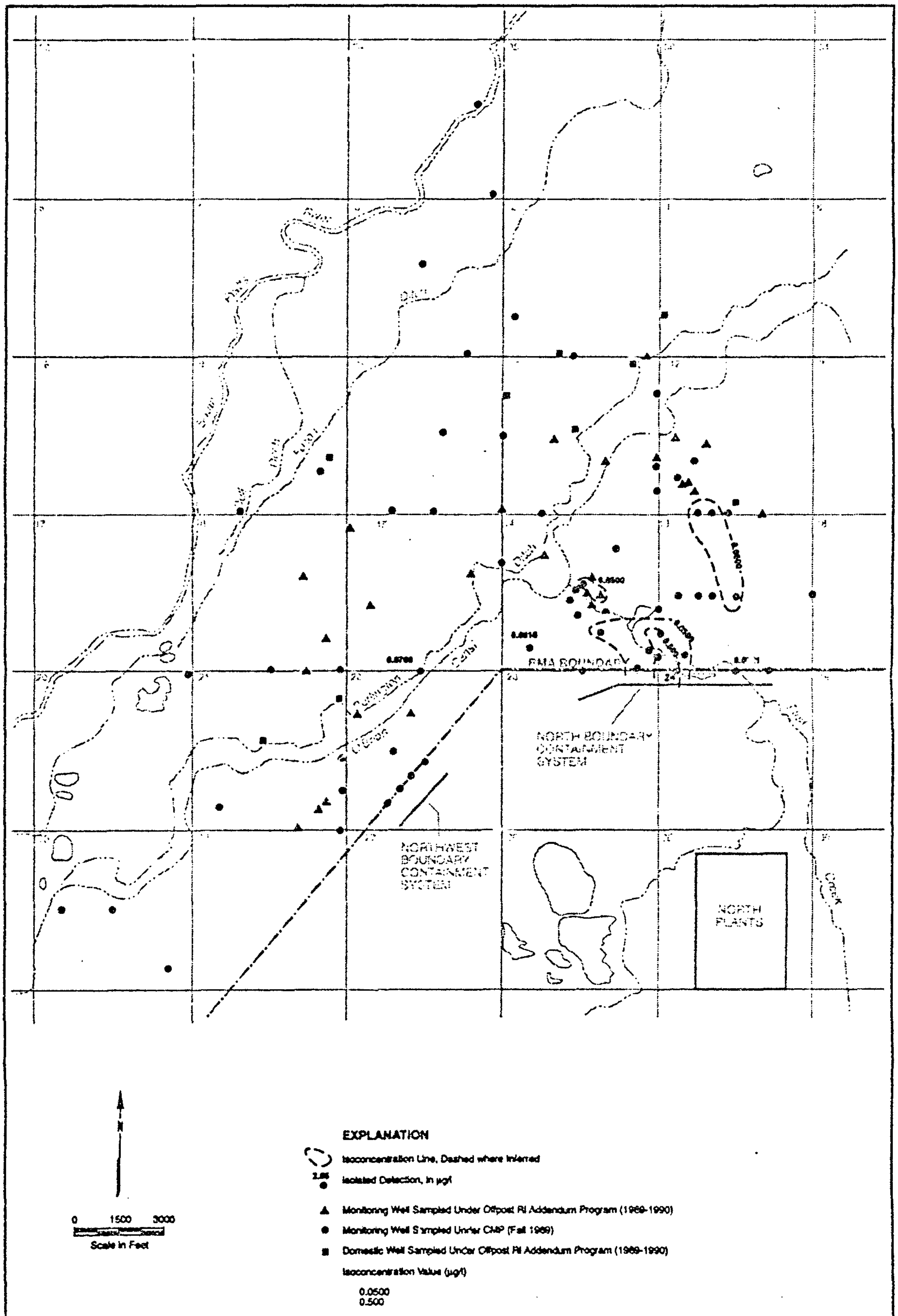
Prepared for: **Program Manager for Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 4 DISTRIBUTION OF DICYCLOPENTADIENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1.1146

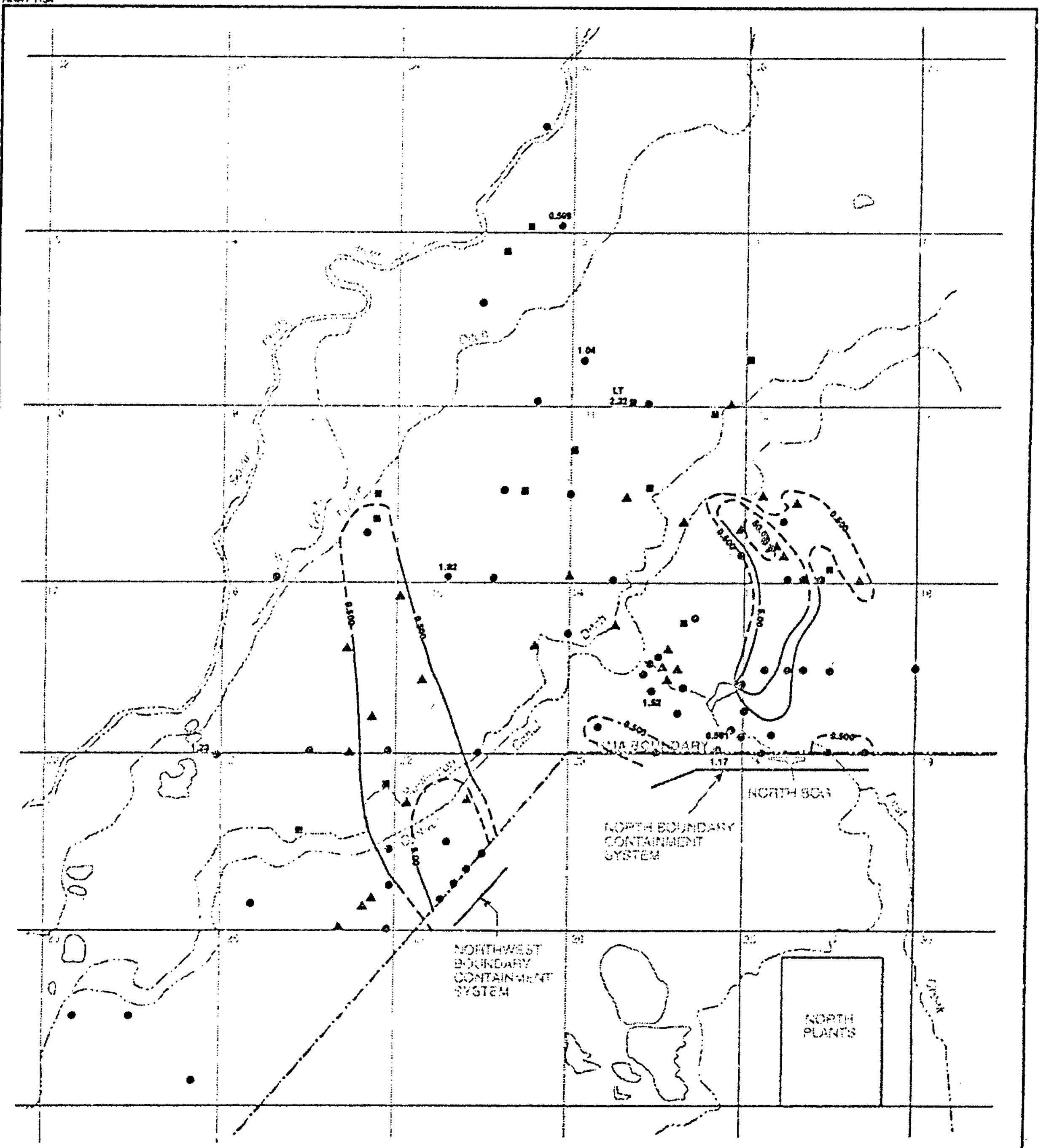


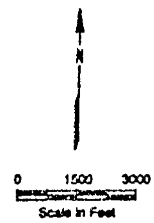
Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 5 DISTRIBUTION OF DIELDRIN IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1147



Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado	Figure 6 DISTRIBUTION OF ENDRIN IN THE OFFPOST UNCONFINED FLOW SYSTEM





EXPLANATION

Concentrations in micrograms per liter (µg/l)

Isoconcentration Line, Dashed where Inferred

2.66 / LT — Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

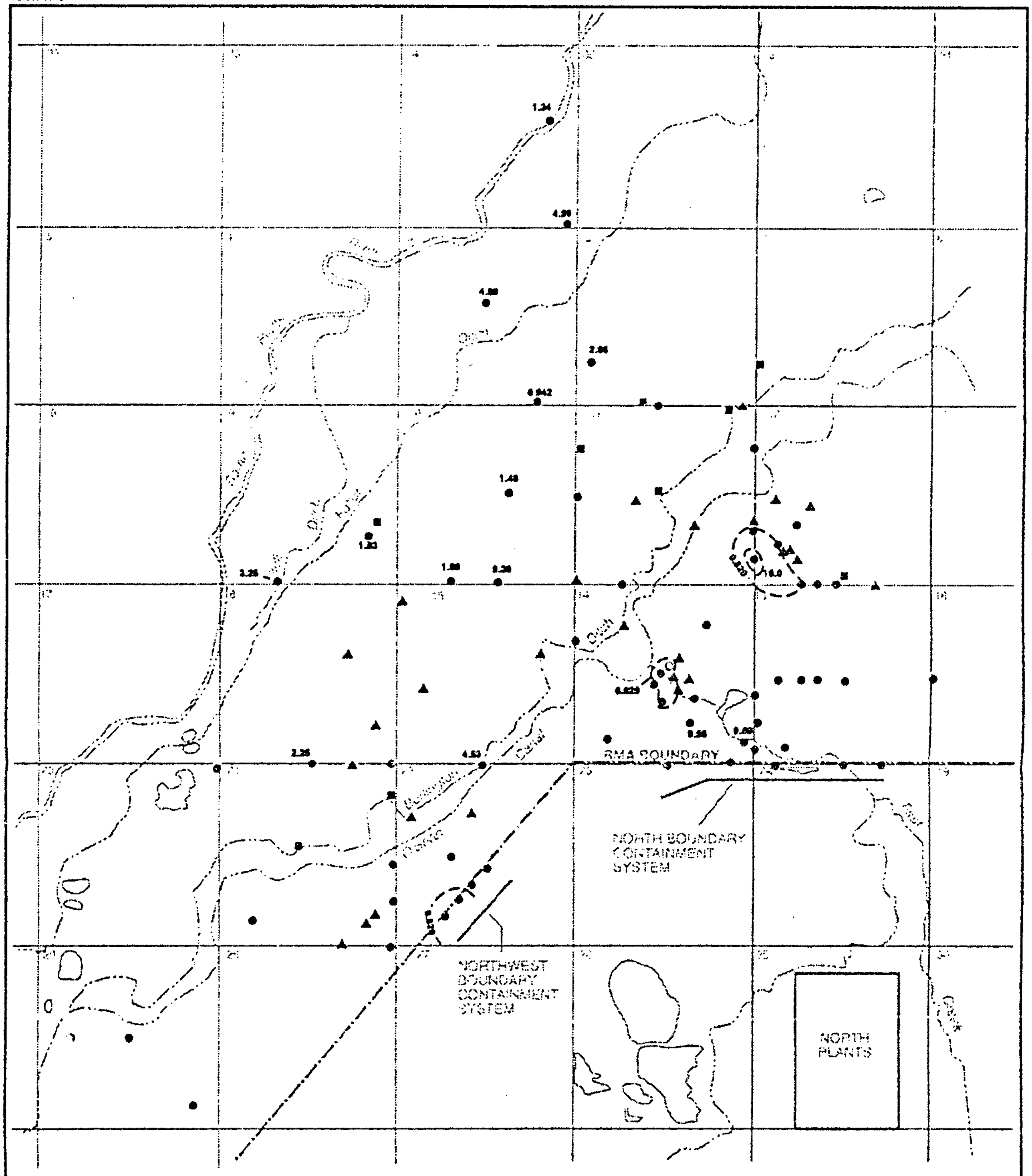
● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)
0.500
5.00
50.0

Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado	Figure 7 DISTRIBUTION OF CHLOROFORM IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1149



EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.93 ● Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

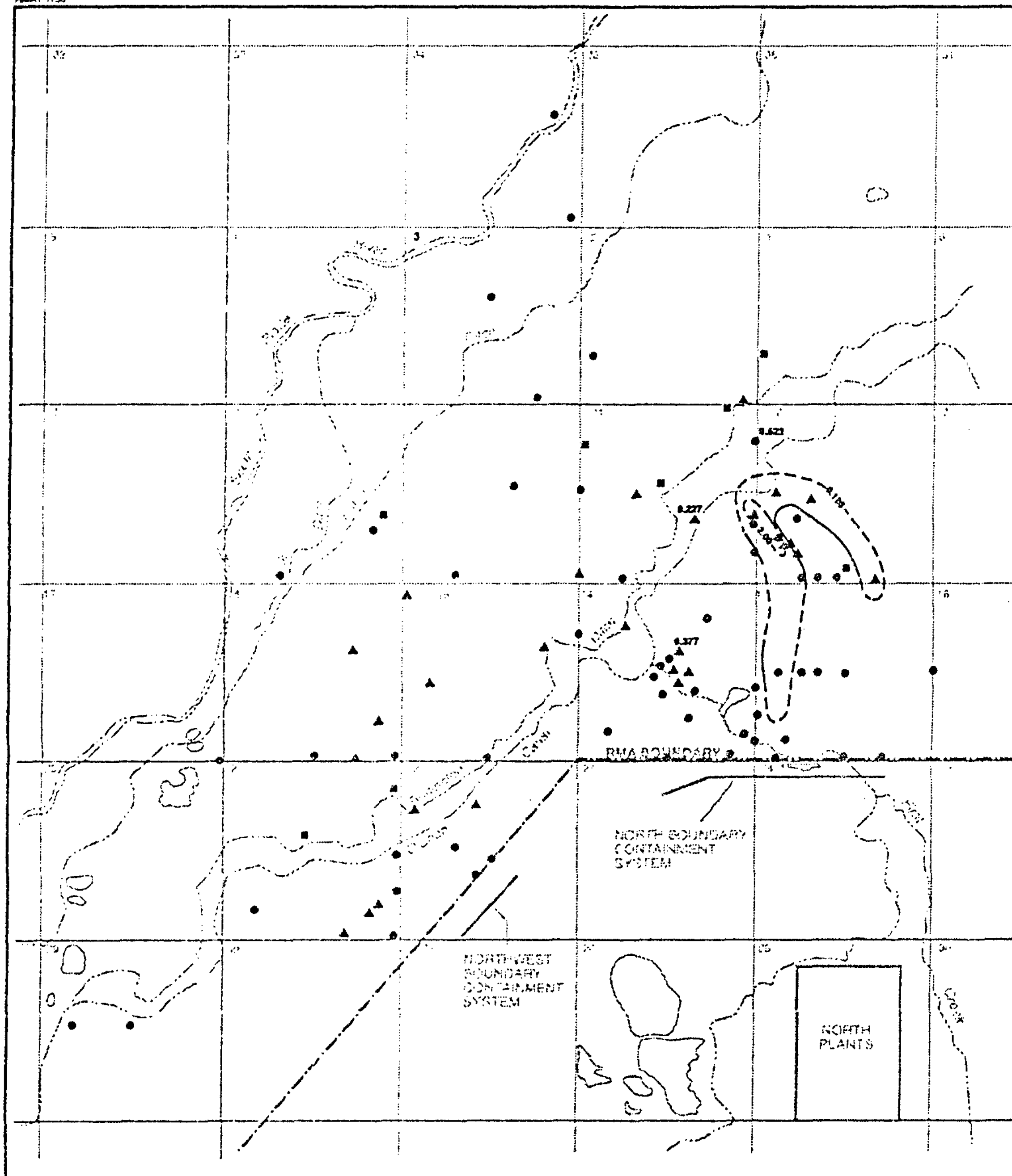
0.820
10.0

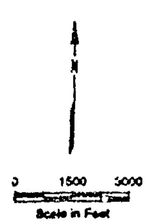
0 1500 3000
Scale in Feet

N

Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado	Figure 8 DISTRIBUTION OF CHLOROBENZENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1150





EXPLANATION

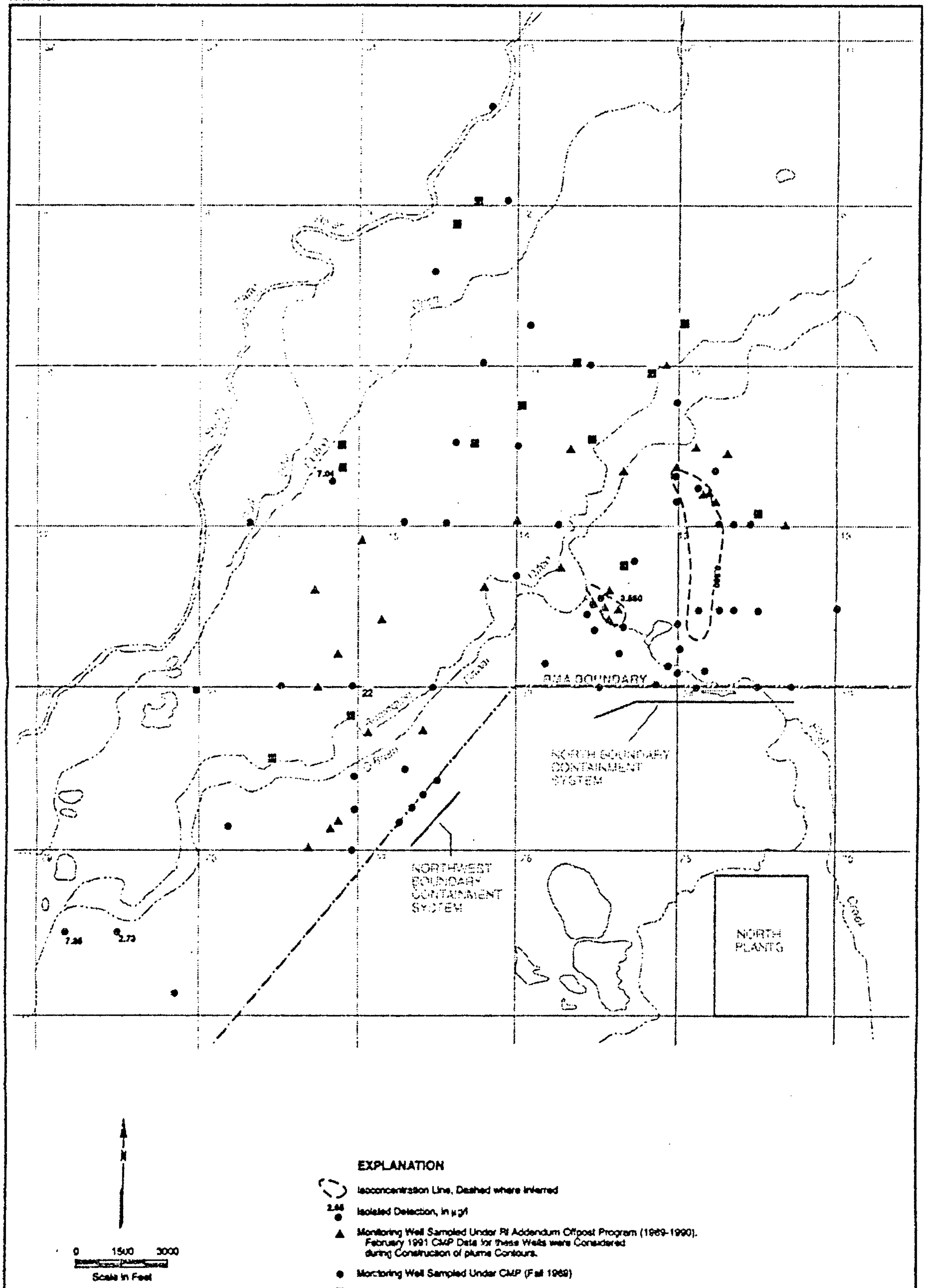
- Isoconcentration Lines, Dashed where Inferred
- Isolated Detection, in µg/l
- Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.
- Monitoring Well Sampled Under CMP (Fall 1989)
- Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.195
2.00

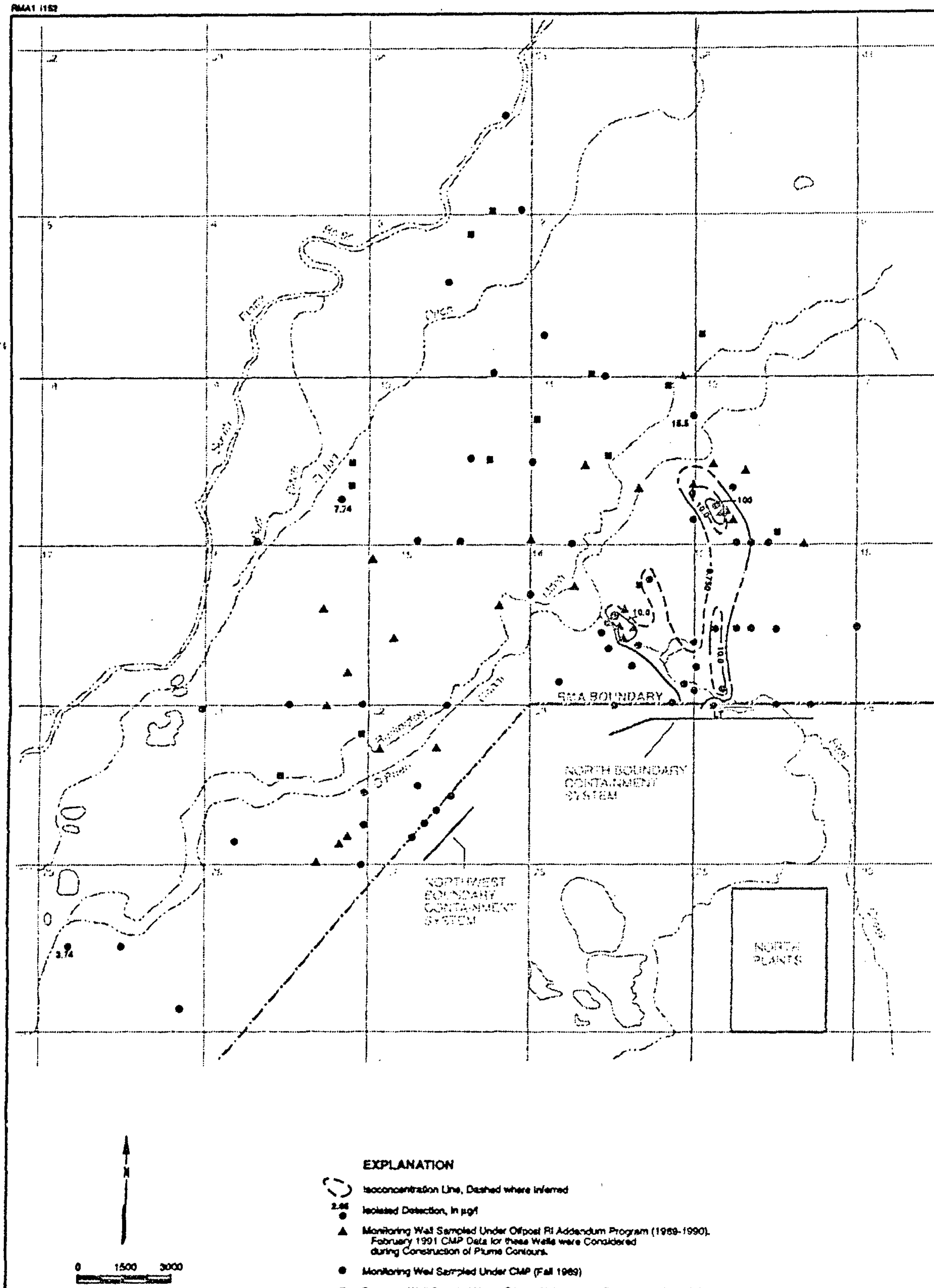
Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado	Figure 9 DISTRIBUTION OF DIBROMOCHLOROPROPANE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1151



Prepared for: **Program Manager for Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 10 DISTRIBUTION OF TRICHLOROETHENE (TRCLE) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1152



EXPLANATION

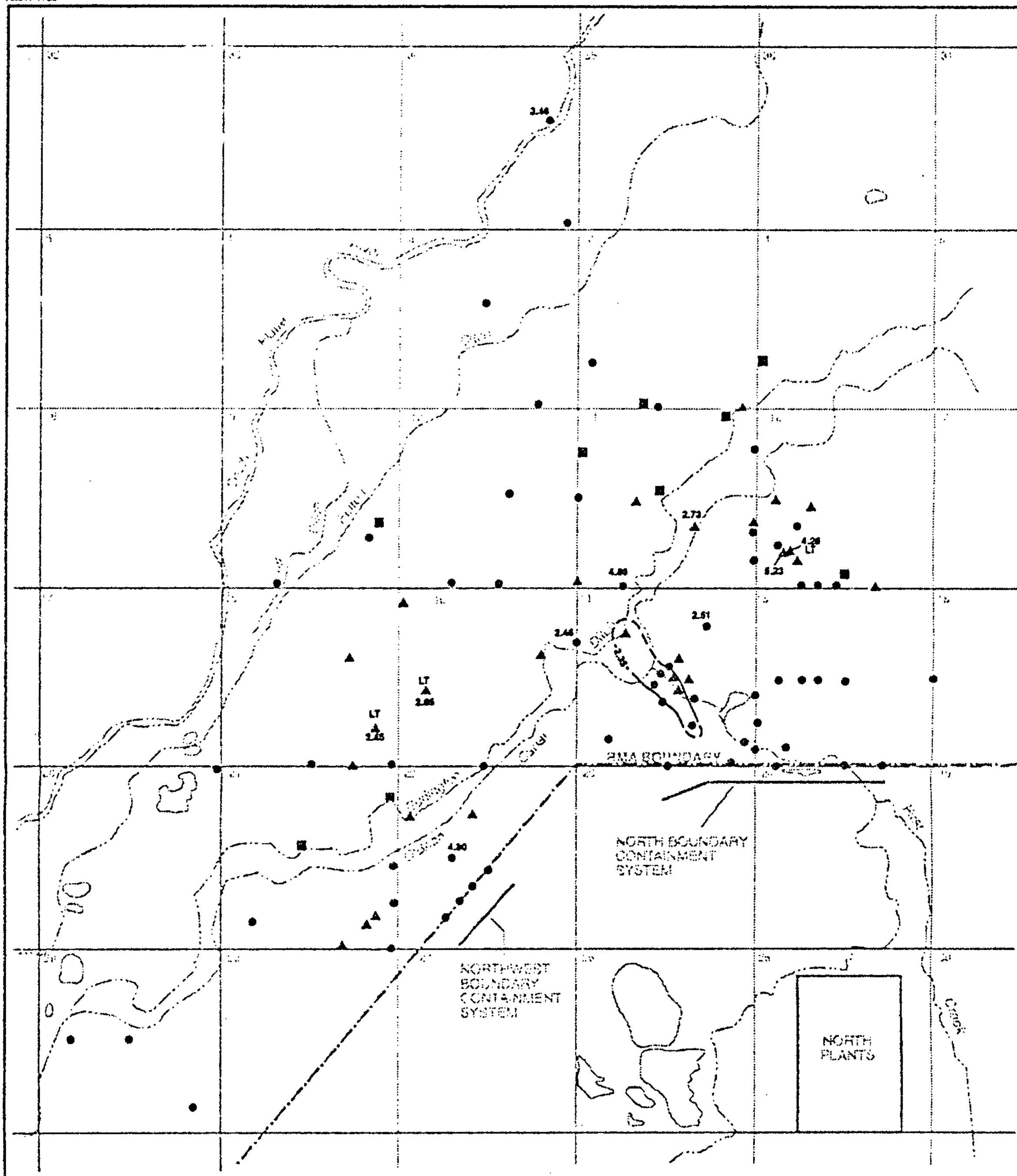
- Isoconcentration Line, Dashed where Inferred
- 2.66 Isolated Detection, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.750
10.0
100

Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 11 DISTRIBUTION OF TETRACHLOROETHENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1153



N

0 1500 3000
Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

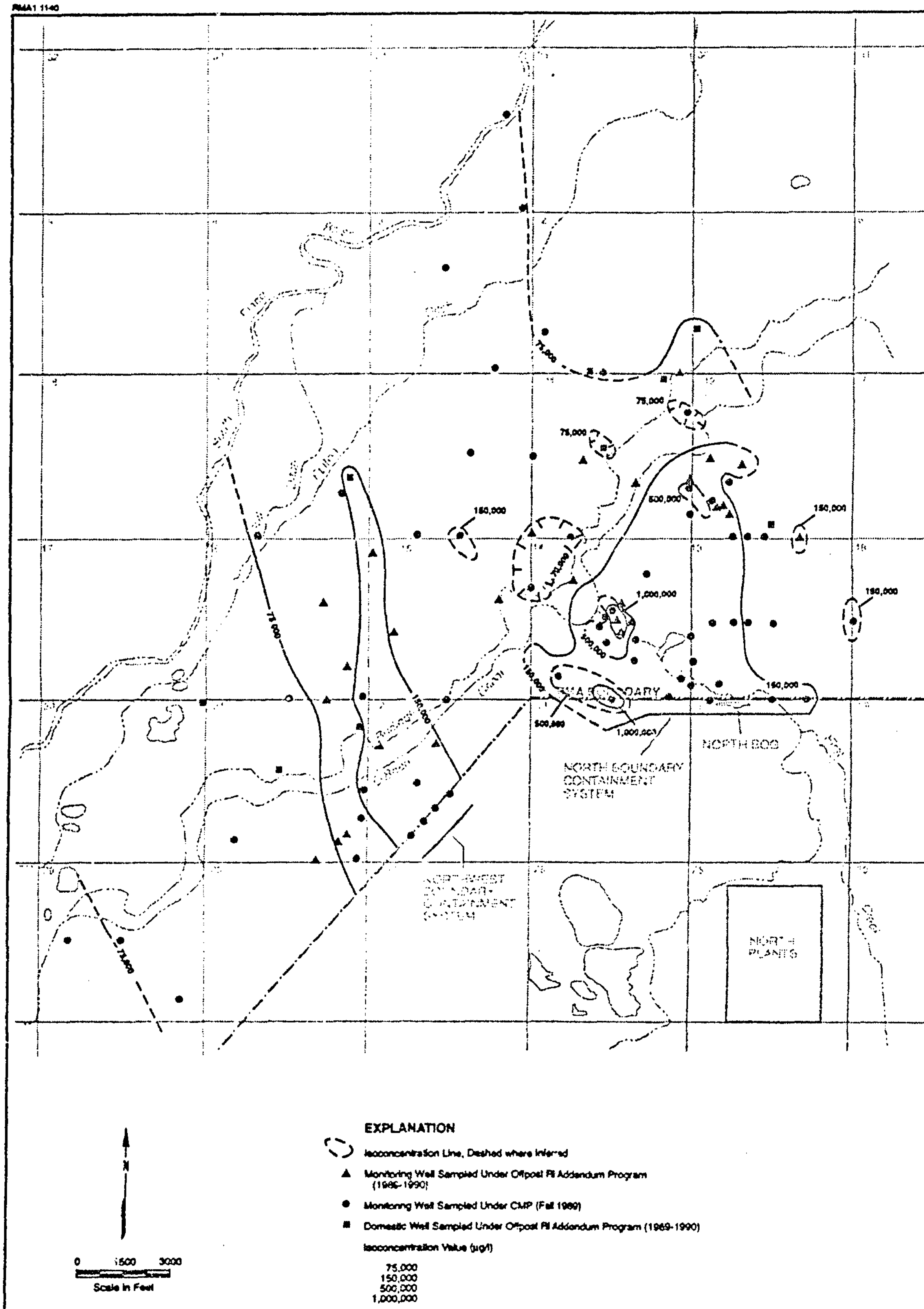
■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2.35

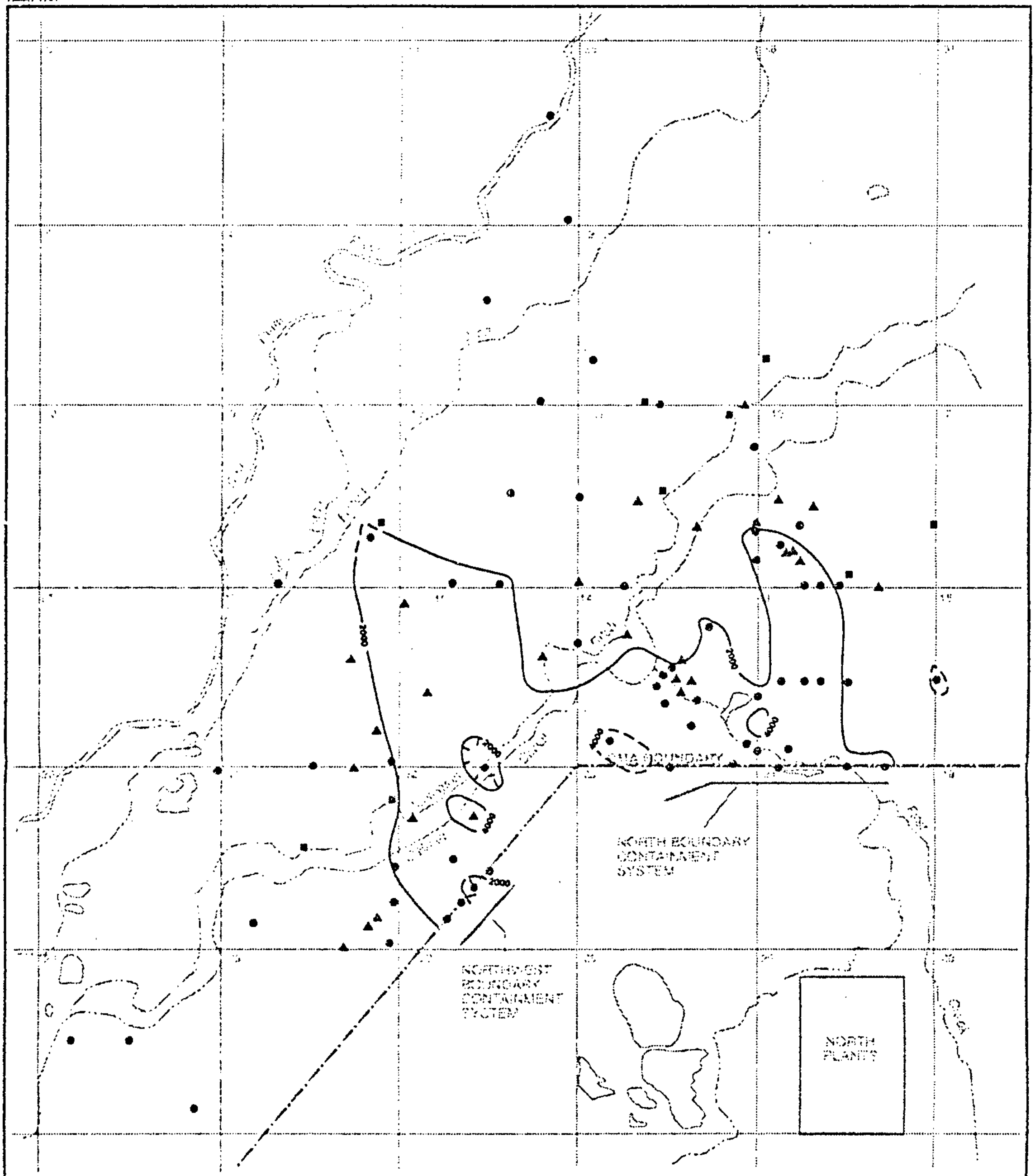
Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 12 DISTRIBUTION OF ARSENIC IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1140



Prepared for: **Program Manager for Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 13 DISTRIBUTION OF CHLORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1141



N

0 1500 3000
Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.96 Isolated Detection or Concentration Less Than Lowest Isoconcentration Value, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (IRA-A and RI Addendum, 1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

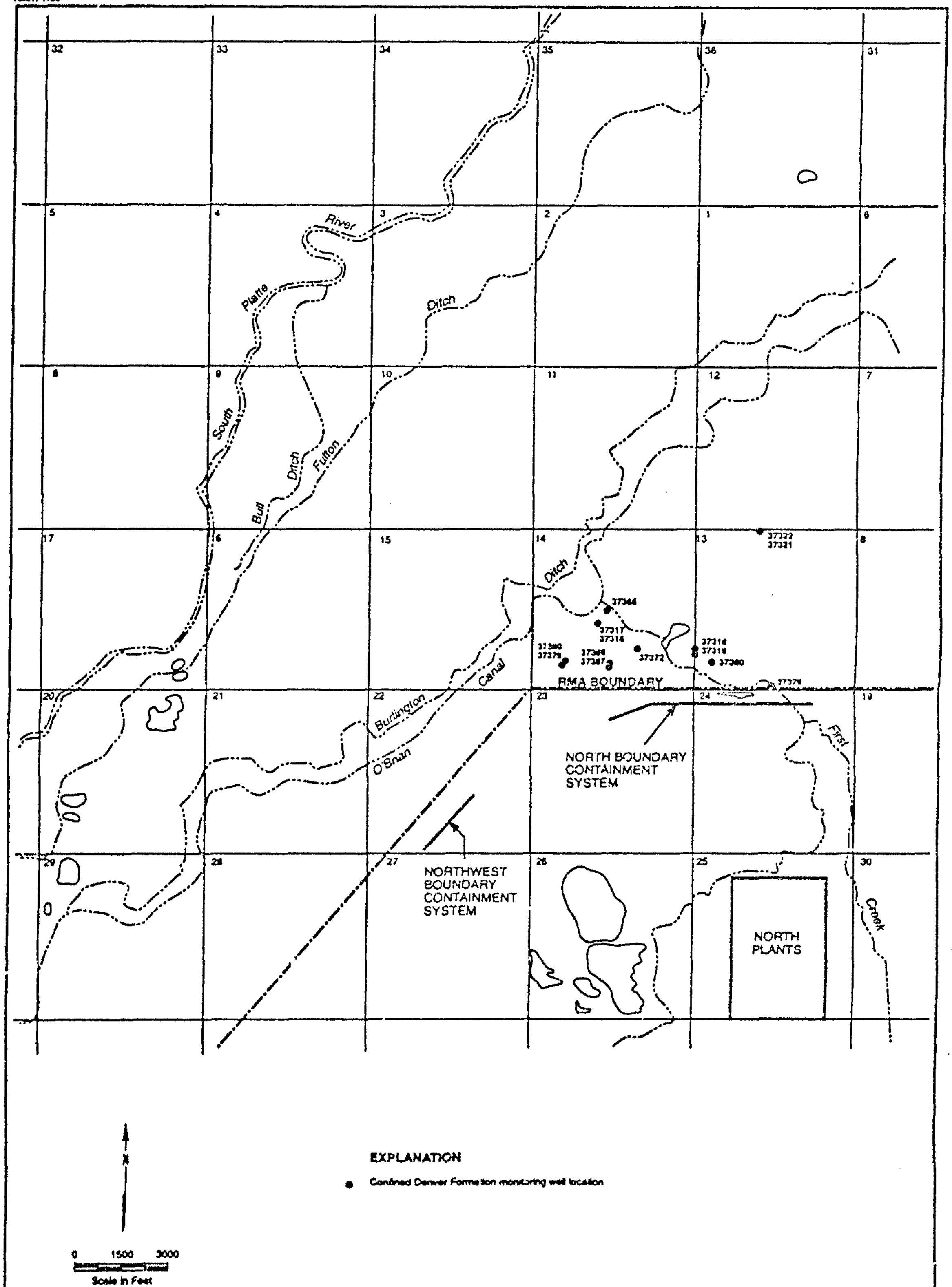
■ Domestic Well Sampled Under RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2000
4000

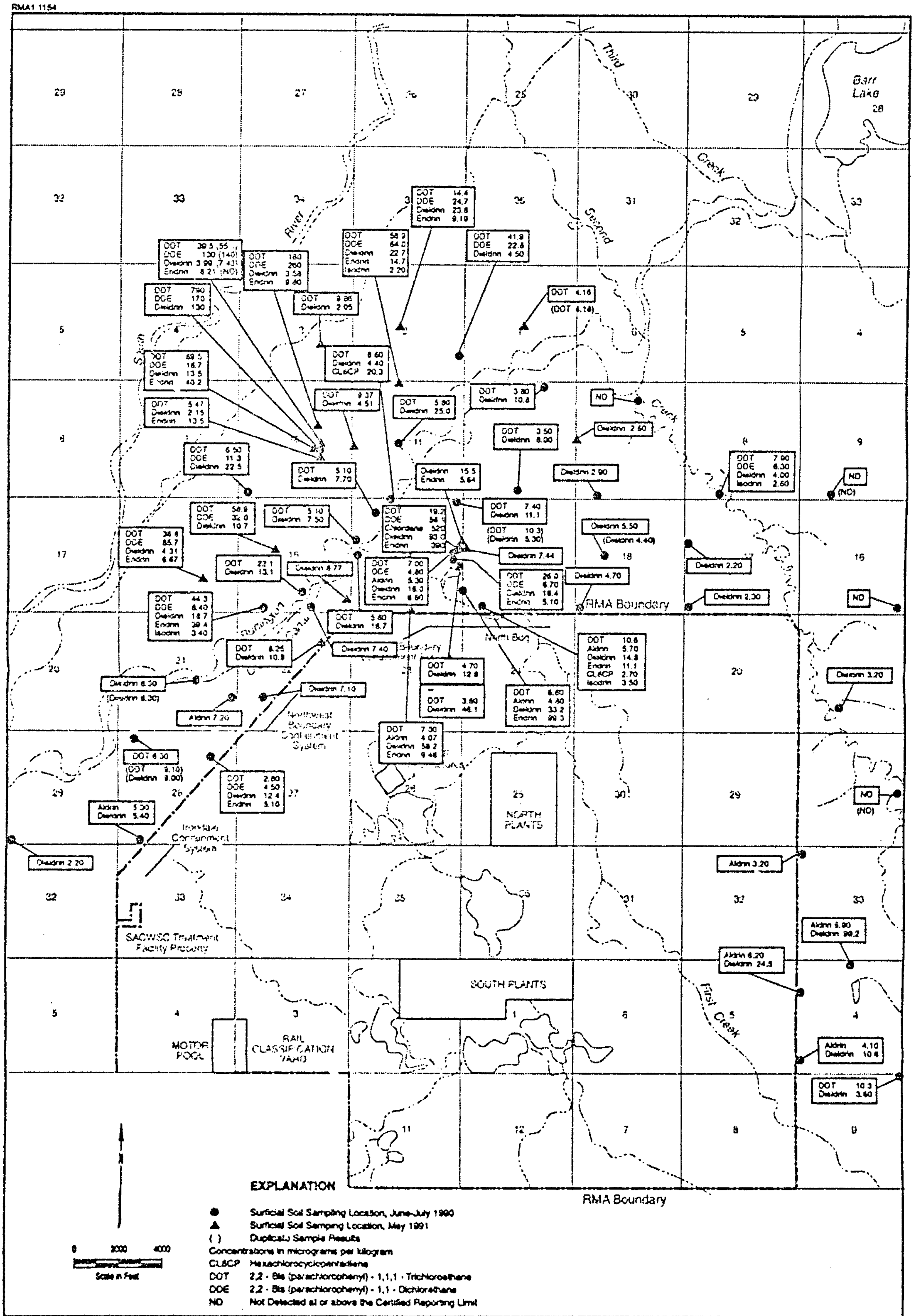
Prepared for: **Program Manager for Rocky Mountain Arsenal** Commerce City, Colorado	Figure 14 DISTRIBUTION OF FLUORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1130



Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 15 OFFPOST OPERABLE UNIT CONFINED DENVER FORMATION MONITORING WELL NETWORK

RMA1 1154



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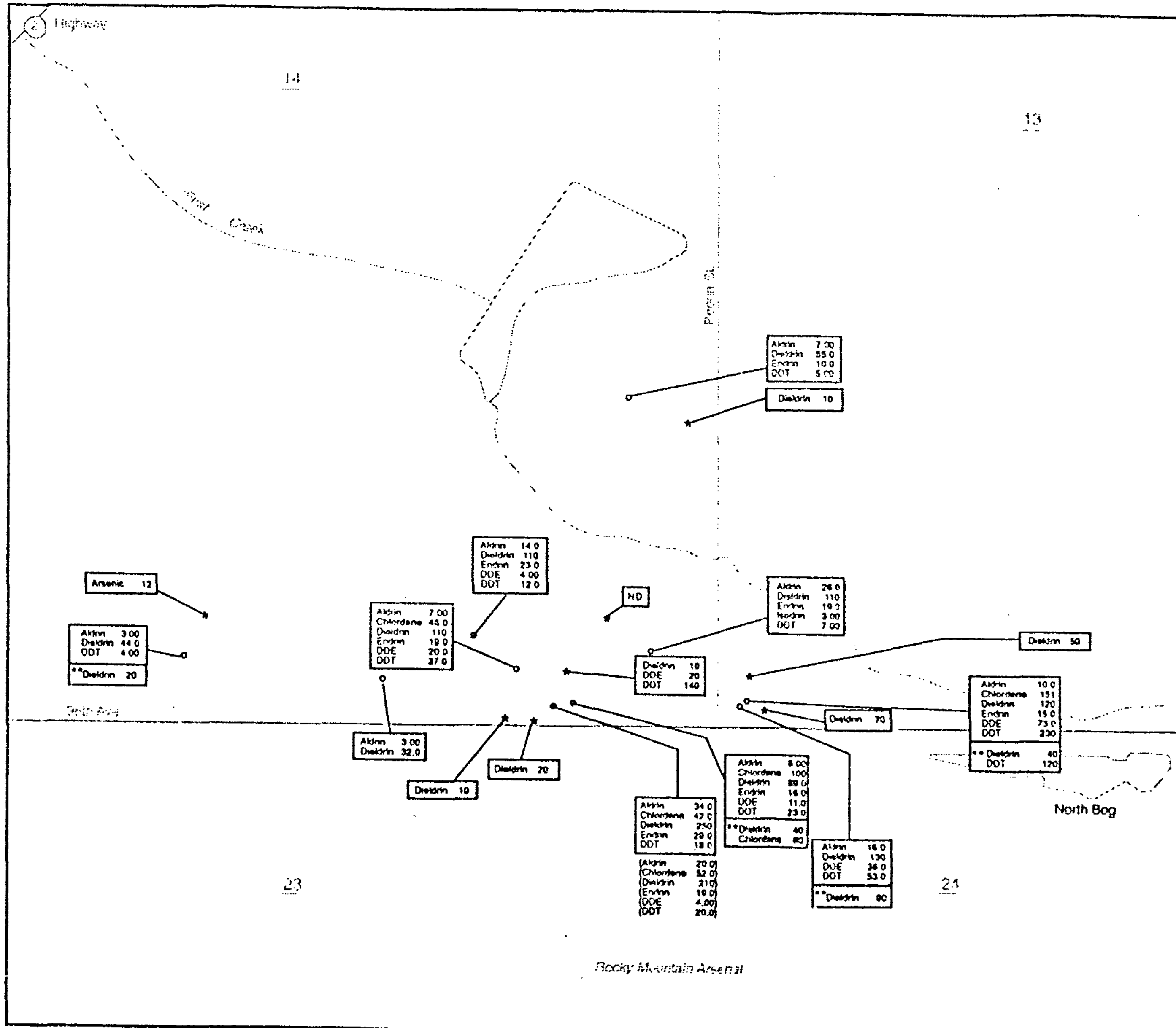
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 16

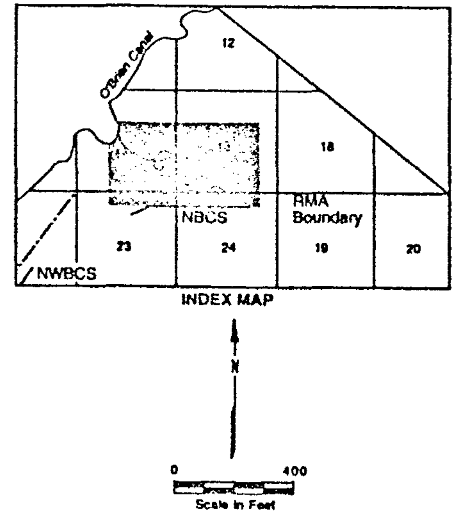
DISTRIBUTION OF ORGANOCHLORINE PESTICIDES DETECTED IN OFFPOST SOIL

RMA1 1194



EXPLANATION

- o Surficial Soil Sampling Location, February 1989
- ( ) Duplicate Sample
- ★ CDH Surficial Soil Sampling Location, February 1989
- 13 Section Number
- CDH Colorado Department of Health
- HLA Harding Lawson Associates
- ★★ Indicates CDH Results for Samples Collocated with HLA Samples
- DDT 2,2 - Bis (parachlorophenyl) - 1,1,1 - Trichlorothane
- DDE 2,2 - Bis (parachlorophenyl) - 1,1 - Dichloroethene
- Concentrations in micrograms per kilogram
- ND Not Detected at or above the Certified Reporting Limit



INDEX MAP

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Figure 17

DISTRIBUTION OF ORGANOCHLORINE PESTICIDES DETECTED IN 96TH AVENUE AREA OFFPOST SOIL

RMA1 1143

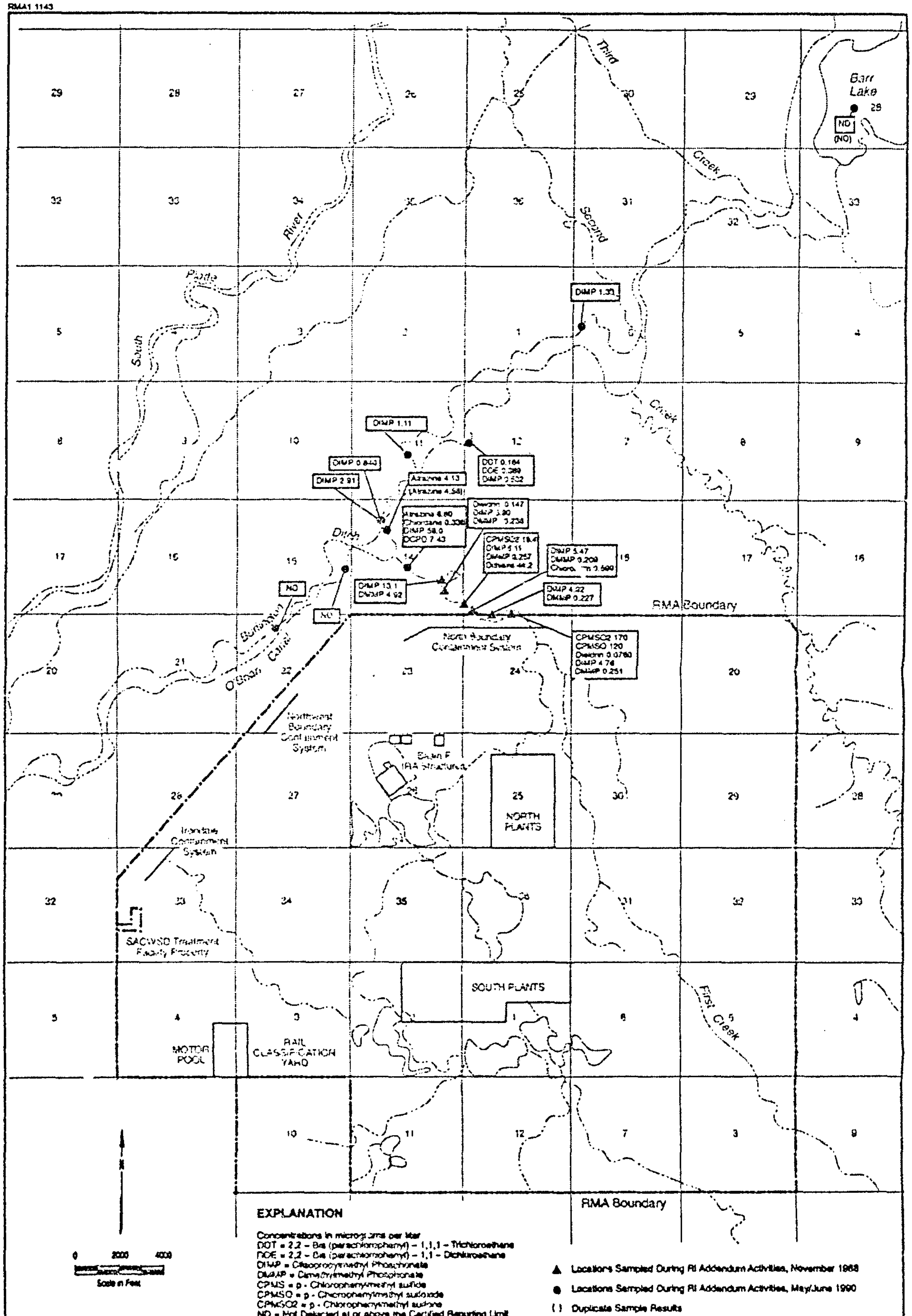

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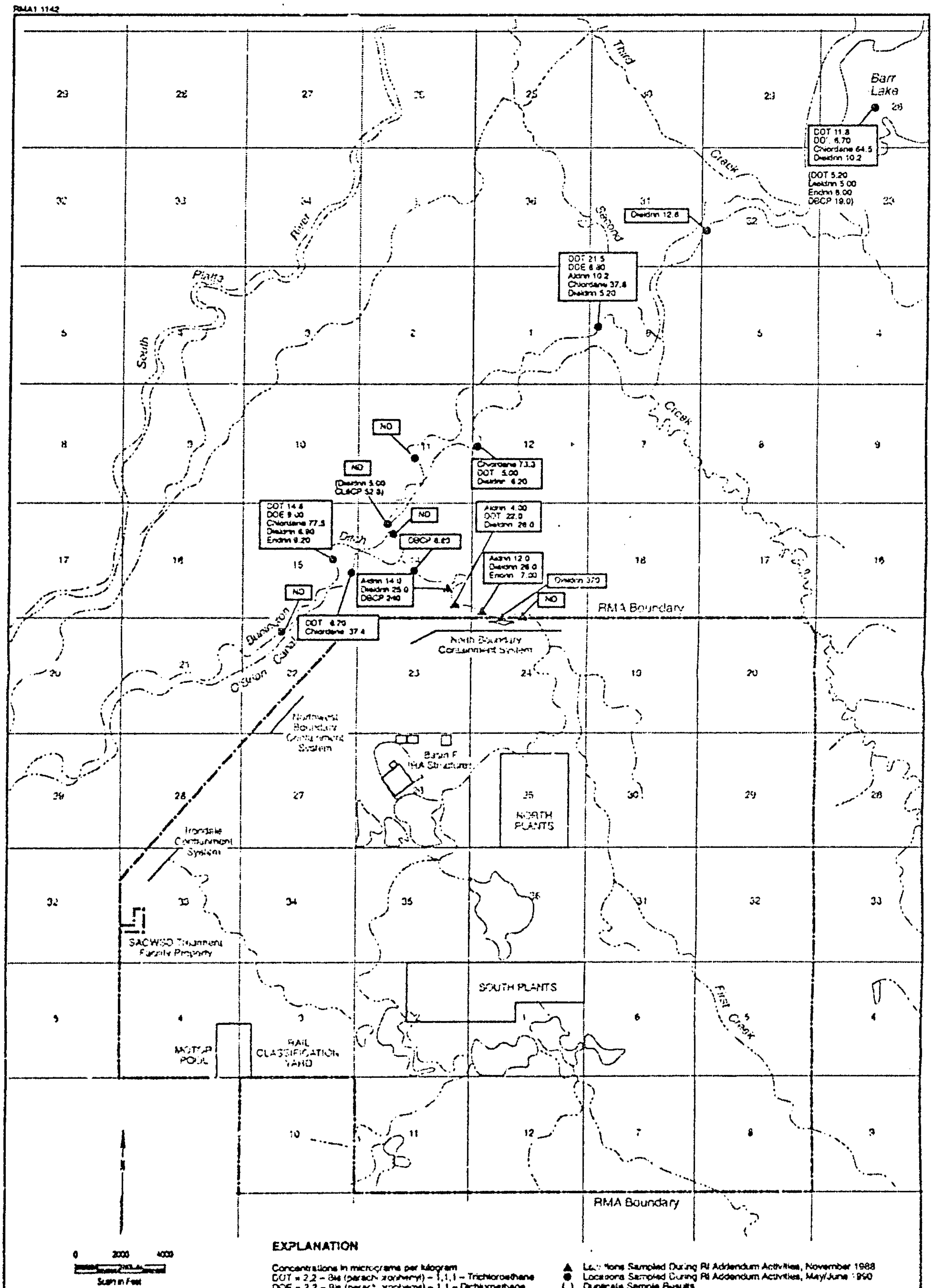
Figure 18

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT SURFACE WATER

RMA1 1142



EXPLANATION

Concentrations in micrograms per kilogram
DDT = 2,2 – Bis (parachlorophenyl) – 1,1,1 – Trichloroethane
DDE = 2,2 – Bis (parachlorophenyl) – 1,1 – Dichloroethane
DBCP = Dibromochloropropane
ND = Not Detected at or above the Certified Reporting Limit

▲ Locations Sampled During RI Addendum Activities, November 1988
● Locations Sampled During RI Addendum Activities, May/June 1990
( ) Duplicate Sample Results

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Figure 19

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT STREAM-BOTTOM SEDIMENT

GLOSSARY

µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
ABS	chemical-specific absorption factor
ACGIH	American Conference of Government Industrial Hygienists
AChE	acetylcholinesterase
ACL	Alternate Concentration Limit
ADI	acceptable daily intake
AHPA	Archeological and Historic Preservation Act
ANOVA	Analysis of Variance
AOP	advanced oxidation process
APEG	alkali metal polyethane glycol
AQCDs	Air Quality Criteria Documents
ARAR	applicable or relevant and appropriate requirement
ARES	Automated Risk Evaluation System
Army	U.S. Department of the Army
AT	averaging time
ATP	adenosine triphosphate
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAC	Biotechnology Advisory Committee
BAF	bioaccumulation factor
BCF	bioconcentration factor
BCRL	below certified reporting level
BCS	Boundary Containment System
BDAT	best demonstrated technology

BDL	below detection limit
BEPA	Bald Eagle Protection Act
BEST	basic extraction sludge treatment
BF	bioavailability factor
BGEPA	Bald and Golden Eagle Protection Act
bgs	below ground surface
BHC	benzene hexachloride
BMF	biomagnification factor
BOD	Biological Oxygen Demand
bw	body weight
C/I	commercial/industrial
CAA	Compliance Assurance Agreement/Clean Air Act
CAR	Contamination Assessment Report
CBSG	Colorado Basic Standards for Groundwater
CCP	Composite Correction Plan (CWA)
CCR	Colorado Code of Regulations
CD	Consent Decree
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&I	Colorado Fuel and Iron
CFR	Code of Federal Regulations
cfs	cubic feet per second/confined flow system
cfs/mi	cubic feet per second per mile
CHWMA	Colorado Hazardous Waste Management Act
cm	centimeters
cm/sec	centimeters per second
cm/hr	centimeters per hour

cm^2	centimeters squared
CMP	comprehensive monitoring program
CNS	central nervous system
COC	chemical of potential concern
COD	Chemical Oxygen Demand
COE	U.S. Army Corps of Engineers
CPMS	4-chlorophenylmethyl sulfide
CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
C_r	concentration in plant roots/tubers
CRL	certified reporting limit
CSC	Chemical Sales Company
CTM	cattail marshes
CU	consumptive use
CV	coefficient of variation
C_w	chemical concentration in water
CWA	Clean Water Act
D_a	molecular diffusivities in air
DAA	detailed analysis of alternatives
days/yr	days per year
DBCP	dibromochloropropane
DDD	2,2-bis (para-chlorophenyl)-1,1-dichloroethane
DDE	2,2-bis (para-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane
DDTR	DDT and its metabolites
DIMP	diisopropyl methylphosphonate
DNA	deoxyribonucleic acid

DOC	dissolved organic carbon
DQO	data quality objective
DRCOG	Denver Regional Council of Governments
DRE	Destruction/Removal Efficiency
DSA	development and screening of alternatives
DSMA	disodium methanearsonate
D_w	molecular diffusivities in water
EA	endangerment assessment
Ebasco	Ebasco Services, Inc.
EC_{50}	median effective concentration
ED	exposure duration
EDB	ethylene dibromide
EF	exposure frequency
EFH	Exposure Factors Handbook
Eh	redox potential
EPA	U.S. Environmental Protection Agency
ERT	Environmental Research and Technology
ESA	Endangered Species Act
ESE	Environmental Science and Engineering, Inc.
ET	exposure time
FF	fallow field
FFA	Federal Facility Agreement
FI	locally produced fraction
FS	feasibility study
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year

FWCA	Fish and Wildlife Coordination Act
FWPCA	Federal Water Pollution Control Act
FWRIR	Final Water Remedial Investigation Report
FY	Fiscal Year
FY88	fiscal year 1988
FY90	fiscal year 1990
g/cm^3	grams per cubic centimeter
g/l	grams per liter
g/day	grams per day
GAC	granulated activated carbon
GC/MS	gas chromatography/mass spectroscopy
GMP	groundwater monitoring program
gpm	gallons per minute
GPS	Groundwater Protection Standards
GWF	grasses and weedy forbs
HA	health advisory
HADs	Health Assessment Documents
HBC	health-based criteria
HDPE	High Density Polyethylene
HEA	Health Effects Assessment
HEAST	Health Effects Assessment Summary Tables
HEEDs	Health and Environmental Effects Documents
HEEPs	Health and Environmental Effects Profiles
HEW	Health Education and Welfare
HI	Hazard Index
HLA	Harding Lawson Associates
HQ	hazard quotient

hr/day	hours per day
HSBAA	Historic Sites, Buildings, and Antiquities Act
HSDB	Hazardous Substance Database
HSWA	Hazardous and Solid Waste Amendments
ICP	inductively coupled plasma
ICS	Irondale Containment System
IRA	Interim Response Action
IRA A	Additional Interim Response Action
IRF	In Situ Radio Frequency
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISV	in-situ vitrification
K_{oc}	organic carbon coefficient
K_{ow}	octanol/water partition coefficient
l/day	liters per day
l/kg	liters per kilogram
l/cm^3	liters per centimeter cubed
LAER	Lowest Achievable Emission Rate
lb/acre	pounds per acre
LC_{50}	chemical concentration that is lethal to 50 percent of the exposed population
LD_{50}	chemical dose that is lethal to 50 percent of the exposed population
Ldn	day-night average noise level
LDPE	low-density polyethylene
LDR	Land Disposal Restrictions
LOAEC	lowest-observed-adverse-effect concentration
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration

LOEL	lowest-observed-effect level
m^2/day	square meters per day
MATC	Maximum Allowable Tissue Concentration
MBTA	Migratory Bird Treaty Act
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MER	Colorado Division of Water Resources Master Extract Register
MF	modifying factor
MFO	mixed function oxidose enzymes
mg/kg-bw-day	milligrams per kilogram body weight per day
mg	milligrams
mg/cm^2	milligrams per cubic centimeter
mg/kg/day	milligrams per kilogram per day
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mg/m^2/day	milligrams per meter squared per day
mg/m^3	milligrams per cubic meter
mi^2	square miles
MKC	Morrison-Knudsen Corporation
MKE	Morrison-Knudsen Engineers, Inc.
MKES	MK-Environmental Services
ml/g	milliliters per gram
MLE	most likely exposure
MOP	Method of Proportion
MP	Malcolm-Pirnie, Inc.
MRL	minimal risk level
MSL	Mean Sea Level

MSMA	monosodium methanearsenate
MTV	mobility, toxicity, and volume
N	nitrogen
NAAQS	National Ambient Air Quality Standards (CAA)
NAS	National Academy of Sciences
NBCS	North Boundary Containment System
NCI	National Cancer Institute
NCP	National Contingency Plan
NEPA	National Environmental Policy Act (1969)
NESHAPS	National Emissions Standards for Hazardous Air Pollutants (CAA)
NHPA	National Historic Preservation act
NIOSH	National Institute for Occupational Safety and Health
nm	nanometers
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NOAEC	no-observed-adverse-effect concentration
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NPDES	National Pollutant Discharge Elimination System (CWA)
NPDWS	National Primary Drinking Water Standards
NPL	National Priorities List (CERCLA)
NRC	National Research Council
NRCC	National Research Council of Canada
NRDAM/COE	Natural Resource Damage Assessment Model for Coastal and Marine Environments
NSPS	New Source Performance Standards (CAA)
NTP	National Toxicology Program
NWBCS	Northwest Boundary Containment System

O&M NBCS	Operation and Maintenance North Boundary Control System
OCP	organochlorine pesticide
OECD	Organization for Economic Cooperation and Development
OHM/TADS	Oil and Hazardous Material/Technical Assistance Data System
OSWER	Office of Solid Waste and Emergency Response
OTSP	organics in total suspended particulates
OU	operable unit
PACT	powder activated carbon treatment
PC	permeability coefficient
PCNB	pentachloronitrobenzene
PEG	polyethylene glycol
PFF	plowed fallow field
PM-10	respirable particulates less than 10 microns in diameter
PMO	Program Managers Office
PMRMA	Program Manager for Rocky Mountain Arsenal
POTW	publicly owned treatment works
ppm	parts per million
PQL	Practical Quantitation Limit
PRG	preliminary remediation goal
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
R	retardation factor
RA	risk assessment
RACT	Reasonably Available Control Technology
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective

RBC	rotating biological contractor
RCC	Resource Conservation Corporation
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action (CERCLA)
RD	Remedial Design
RfD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RIC	Resource Information Center
RLSA	R.L. Stollar & Associates, Inc.
RMA	Rocky Mountain Arsenal
RME	Reasonable Maximum Exposure
RNA	ribonucleic acid
ROD	Record of Decision
RPM	Remedial Project Manager (CERCLA)
RPO	representative process option
RRC	regulatory risk criteria
RSA	regional statistical area
RTECS	Registry of Toxic Effects of Chemical Substances
SA	skin surface area
SACWSD	South Adams County Water and Sanitation District
SAF	Spatial Adjustment Factor
SARA	Superfund Amendments and Reauthorization Act (1986)
SAS	Statistical Analysis System
SDWA	Safe Drinking Water Act
SEP	Standard Evaluation Procedure
SF	slope factor

SGOT	serum glutamate-oxymate aminotransferase
SIP	State Implementation Plans
SUTRA	Saturated-Unsaturated Transport
SVOC	semivolatile organic compound
TAC	time for exchange of basement air
TBC	to be considered
TCHD	Tri-County Health Department
TCOC	tissue chemicals of concern
TERIS	Teratogen Information System
TG-W	tall grass wetlands
TICs	tentatively identified chemicals
TLV	threshold limit value
TPP	technical program plan
TRCLE	trichloroethylene
TRV	toxicity reference value
TSD	Technical Support Document (or) Treatment, Storage, and Disposal
TSP	total suspended particulates
TSS	total suspended solids
TWA	time-weighted average
UAFS	unconfined alluvial flow system
UF	uncertainty factor
UFS	unconfined flow system
UIC	Underground Injection Control
UL90	upper 90 percent confidence limit on the arithmetic mean
UL95	upper 95 percent confidence limit on the arithmetic mean
USABRDL	U.S. Army Biomedical Research and Development Laboratory
USAF	U.S. Air Force

USC	Unified Soil Classification (or) United States Code
USDA	U.S. Department of Agriculture
USDHEW	U.S. Department of Health Education and Welfare
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	universal transverse mercator
USC	United States Code
UV	ultraviolet
VAR	ratio of basement volume to surface air in contact with soil
VLT	very low toxicity
VOC	volatile organic compound
WES	U.S. Army Engineer Waterways Experiment Station
WF	weedy forbs
WHO	World Health Organization
WQC	water quality criteria
WQCA	Water Quality Control Act
WWC	Woodward-Clyde Consultants
°C	degrees Celsius